JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CLIV, NO. 1. 77TH YEAR. JULY, 1902

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal.*

Mining and Metallurgical Section.

Read at the Stated Meeting, held Wednesday, December 11, 1901.

Upon the Structure of Metals and Binary Alloys.

BY WILLIAM CAMPBELL, B.Sc. (Durham), F.G.S.

In the following paper the author has tried to illustrate the constitution of binary alloys by a few notes upon the structure of metals and alloys. The methods of obtaining a knowledge of the structure of metals and alloys are first discussed, then the crystalline structure of metals, the effects of strain and the effect of heat treatment are illustrated. Finally, the various groups of binary alloys are set forth and the constitution of several examples, representative of the various groups as far as possible, is shown by contrasting or rather by drawing a parallel between their cooling curves and microstructure. The whole of the original work of the paper was carried out at the Royal School of Mines, London, and in the Metallurgical Department of Columbia University.

The magnification and illumination of the various photographs of the structure of metals and alloys are represented by the symbol in the lower right-hand corner, thus: x 33. v. means multiplied thirty-three diameters and vertically illuminated; or x 16. o. means multiplied sixteen diameters and obliquely illuminated.

PRACTICAL METALLOGRAPHY.

Practical metallography may be divided into several distinct parts:

(1) Preparation of alloys or metal to be examined.
(2) Preparation of surface.
Cutting and polishing.
(3) Etching the prepared surface: development of structure.
(4) Microscopical examination.
Mounting the specimen.
Microscope and accessories.
(5) Microphotography.

It would be out of place to do more than glance at one or two of the main points in preparing and examining sections, because the subject has been carefully treated by Stead, Le Chatelier, Sauveur and many others. One of the most important points is the preparation of the alloy or metal, because its final structure will in almost every case depend upon its rate of cooling, the uniformity of cooling, prevention of oxidation, etc., and, in the case of an alloy, upon the thorough mixing of its constituent metals when liquid. As a general rule, the slower the cooling the larger the structure. In many metals and alloys, this holds good not only during solidification, but also afterwards, because profound changes often take place long after solidification. As examples, one immediately thinks of iron and its alloys, of the bronzes and of the brasses. As an example of the necessity for guarding against oxidation, we need only consider copper and the rapidity with which its oxide diffuses through it.

There are several devices to insure slow and uniform cooling. Where a gas furnace is used, automatic cut-offs give

good results. Heycock and Neville* have invented one which will give any desired rate of cooling. It consists of a tube some 15 centimeters long by 2½ centimeters wide, and contains an inner tube made of many layers of fine silk wound round the outside of a cylinder of coarse iron wire gauze to give it rigidity. With the exception of a line about 2 millimeters wide, running from top to bottom of the silk, the whole of this inner tube is coated with a very viscous shellac. The silk tube is open at its lower end, which dips into mercury, whilst its upper end is cemented to a glass tube connected with the gas supply from a regulator which supplies the gas at a constant pressure. The outer tube has an opening at its base, through which mercury is admitted, and an exit pipe near the top through which the gas passes to the furnace. Thus, the gas from the regulator enters the inner tube at the top, and passes through that part of it which is not covered by shellac into the outer tube and thence to the furnace. If mercury is forced into the outer tube, the gas is slowly cut off. A uniform supply of mercury is obtained from a cylinder above which is a head of water. This head of water is increased at a uniform rate by means of a constant level water dropper whose supply can be increased or decreased at will. Thus, as the head of water slowly and uniformly increases, the pressure on the surface of the mercury increases, causing it to flow into the cut-off tube and rise inside and out of the silk tube, and hence to gradually cut off the escape of gas through the unvarnished portion. In the case of alloys melting at high temperatures, we can allow sufficient gas to pass direct to the furnace by the aid of a by-pass, to keep it at the lowest temperature required, the cut-off thus becoming more efficient. Where ordinary coke fires are used a simple method can be employed which gives very good results. The alloy is made in a small crucible, and when well molten and thoroughly mixed the whole is placed in a hot, larger crucible in place in a bright fire. The outer crucible is filled with charcoal and charcoal powder, to

* Trans. Chem. Soc., 1898. No. 73, p. 714.

prevent oxidation, and the lid put on; a few pieces of hot coke are placed on top and then the fire-place is filled up with hot ashes; all dampers are closed to shut off as much draught as possible, and the whole is allowed to cool slowly. In this way the size of the structure of the alloy can be increased from ten to twenty times.

Oxidation can usually be prevented by having a good supply of charcoal on top of the alloy. In the case of many alloys whose melting-points are comparatively low, such as the tin antimony series, potassium cyanide is an excellent material to use. In the ordinary way, where very slow cooling is not necessary, some potassium cyanide is melted in a plumbago crucible. The two metals are then added, and when fluid the crucible is shaken, taken out of the furnace and allowed to cool slowly in the open air. When cool, the cyanide is washed away and the alloy taken out.

It is always necessary to thoroughly mix the constituents of an alloy, but in many cases solution and diffusion help materially to form the alloy. For example, to prepare the eutectic alloy of the copper-tin series (1 per cent. Cu, 99 per cent. Sn) the tin is first melted and the copper added in the form of foil. Although the temperature may only be between 350° and 400° C., the tin rapidly dissolves the copper, which diffuses uniformly throughout the whole mass. In most cases, if the whole contents of the crucible be liquid, a good shake of the crucible produces a uniform alloy. In some cases, however, as for instance the aluminium-bronzes, shaking or even stirring does not always produce a uniform alloy. It is then best to cast the alloy and break it up into small fragments or to granulate it and remelt till the desired result is obtained.

Having obtained our metal or alloy, the next process is to obtain a suitable piece to polish. A convenient size is one from $\frac{1}{2}$ inch to 1 inch in diameter and about $\frac{1}{8}$ inch thick. In the case of very hard and brittle metals or alloys, a fragment is broken off of convenient size and a face can be ground down on an emery wheel. When we are dealing with metals which can be cut with a saw and filed, a small plate can be prepared. In the case of bars,

rods or rails, much time is saved by using a mechanical saw such as is manufactured by the Millers Falls Manufacturing Company, Mass. With material of a comparatively small size, such as alloys we should prepare, an American hack-saw and a vice are all that is necessary. It is generally advisable to cut a vertical section, because in some cases the structure is not the same at the top and bottom. This is specially the case with alloys whose constituents, the crystals and ground-mass, differ greatly in density; for example, the alloys of tin and antimony. Having obtained a piece of the requisite size, it is now filed comparatively smooth, using a second cut and then a dead smooth file. This is easily performed by holding the file so that the tag rests on the bench and by drawing the section downwards over its surface. When the section consists of some soft material such as lead or tin, care must be taken to keep the file clean, or particles of metal will cling to the file and tend to tear the surface of the section. This tearing effect tends to produce a new crystallization, and unless the metal thus modified is entirely removed during polishing, we obtain, on etching, a structure similar to that produced by rolling or hammering.* This point will be referred to later, when change in the solid is considered.

Having filed the specimen comparatively smooth, it is next rubbed over emery paper or cloth of grade o till all traces of file marks are obliterated. Then it is rubbed over paper or cloth of grade oo till the scratches of the previous paper have disappeared. In some cases it is better to grind on a flat, fine turkey-stone, using either water or oil.

The next part of the process consists of rubbing the specimen over sheets of French emery paper, starting with No. o through oo, ooo to oooo, always stopping as soon as the scratches of the last paper have been removed, and using as little pressure as possible, especially in the case of soft metals or alloys. The emery paper may be attached to a board of suitable size or may be fixed to a disc which

---

*Campbell: A Note on Crystallization Produced in Solid Metal by Pressure. Physical Soc., London, June, 1900.

can be revolved by a machine. These papers must be kept absolutely free from grit or the specimen will be spoilt. The last two grades may be moistened with oil.

On leaving the last emery paper, the specimen is polished on broadcloth or chamois leather covered with a little well-washed rouge and well moistened with water. Some workers use an intermediate stage, with diamontine powder. This also has to be washed before using. The operation is finished when the last traces of the emery scratches have been removed. This final polishing must not be carried too far or the specimen begins to polish in relief and an uneven surface is produced. A rouge-wheel saves a great deal of time in this operation.

Several polishing machines have been used to save time. Professor Martens has designed one to polish a number of specimens at the same time. It consists of a block to carry the sections, which are pressed on the grinding and polishing discs of a power-driven revolving wheel. At the Royal Mint, London, Prof. Sir Wm. Roberts-Austen uses a series of vertical circular blocks, covered by emery papers of varying grades, and driven by a motor. To polish the specimen, he uses a horizontal rouge-wheel, power-driven and cased in with glass to keep it perfectly free from grits. Stead has designed a small, simple and very efficient machine which can be driven by hand or power. It consists of a horizontal revolving wheel; conical blocks with rings for securing the emery paper, cloth or chamois leather in position; these blocks are simply dropped into the recessed wheel and are carried round by friction. Above is a can to hold either water or the solution to be used; a tap allows the water to drop at a uniform rate upon the center of the polishing block. A shield is used for catching any fluid thrown from the wheel when in motion.

Sauveur has recently devised a machine by which polishing is simplified and the time occupied in the operation greatly shortened. The machine carries four discs revolving in a vertical plane and covered with suitable cloths. The four polishing surfaces are fed automatically from above, and shields are provided to catch any fluid thrown

off from the discs when in revolution. He claims that if the samples (of iron) be delivered to the operator after filing them with a smooth file, fifteen and probably more can be prepared in an hour.

The success in polishing depends to a great extent upon the polishing powders. For ordinary work it is found sufficient to use jewelers' rouge which has been carefully washed free from all large particles. We can go further, however, in the preparation of polishing powders and also of emery powders, and obtain an absolutely accurate classification with regard to size. As Le Chatelier points out in his "Notes on the Technology of Microscopic Metallography,"* this can be performed by the washing method used by Schlœsing for the analysis of kaolins. The carbonate of lime present in tap water causes the formation of lumps of coarse and fine material in the process of levigation. Mr. Schlœsing therefore treats the powders to be classified with water containing some 0·1 per cent. nitric acid, which dissolves the carbonate of lime and other salts which may be present, derived either from the water or from the powder treated. When the mixture has settled, the clear liquid is poured off and is replaced by distilled water. The mixture is well stirred and allowed to settle once more. This is repeated till all acid has been removed, when the settling takes a considerably longer time. A little ammonia is now added to help the suspension of the finest particles. The liquid is drawn off at different intervals by means of a syphon, forming a hook at its extremity to prevent the portions which have settled from being disturbed. The different intervals are: fifteen minutes, leaving all the coarse grains unsuitable for polishing; one hour, leaving a powder suitable to start polishing; four hours, when a powder suitable for polishing hard metals, such as iron, is obtained; twenty-four hours, and eight days, when the finest polishing powders are obtained. The last deposit may be precipitated in a few hours by adding a little acetic acid. In conducting these operations absolute cleanliness is necessary. The

* *Metallographist*, January, 1901.

best way to keep the powders is to mix them with soap so as to form a paste. Powdered castile soap is added to the powders whilst still wet, in the proportion of one part of dry soap to ten parts of wet powder. The mixture is melted in a water-bath, well stirred and allowed to cool. Stirring is kept up till the mass commences to thicken, when it is poured into tin tubes like oil-paints, or into paper ones like grease-paints.

Le Chatelier considers the following to be the best powders to use (given in their order of excellence): Alumina derived from the calcination of ammoniacal alum, commercial flour-emery, oxide of chromium derived from the combustion of bichromate of ammonium, and oxide of iron derived from the calcination in air of iron oxalate.

DEVELOPMENT OF STRUCTURE.

The methods used for the development of the structure are numerous. Etching is the one in most general use. It may be performed with acids, concentrated or dilute, with alkalies or other reagents which attack the specimen. In many cases an electric current has been used with great success. We can also use a combined polishing and etching method, polishing in relief or heat-tinting. The method used depends entirely upon the specimen whose structure we wish to develop. When we wish to follow the changes produced by a certain mechanical or thermal treatment, we must use a constant method for developing the structure; but when we are studying alloys, various reagents should be used for etching; polishing in relief and heat treatment should be employed and the results compared, and in this way the nature of the various constituents can be ascertained.

For carburized irons the combined etching and polishing method of Osmond gives very beautiful results. It consists of rubbing the polished section upon a piece of parchment moistened with an infusion of licorice root, together with a little precipitated calcium sulphate. Instead of these two reagents, a 2 per cent. solution of ammonium nitrate may be used. The results are practically the same.

Le Chatelier recommends the use of commercial tincture of iodine diluted with four times its volume of alcohol. The solution is rubbed over the polished specimen with the finger tips several times until a gray film appears. Care must be taken not to etch the specimen too deeply.

Stead describes a tincture of iodine and iodide of potassium (1·25 grains of each in 100 cubic centimeters alcohol) which he uses. He places the specimen on a plate and allows one drop of the tincture per square centimeter. It is left there until the iodine color has disappeared. Wash in water, then in alcohol; dry by means of hot-air blast. If the etching has not gone far enough, the process is repeated.

For irons which show no free ferrite a dilute solution of nitric acid in alcohol (0·5 per cent.) is often used. The specimen is dipped into the solution and the etching watched by means of a strong lens. When the etching has proceeded far enough the specimen is placed under the tap, then soaked in alcohol and afterwards dried. If this method is used in the case of ferrite, under high powers the ferrite will be seen to have a granular appearance, due to over-etching. For low-power work, however, it answers well.

For rapidly developing the structure of steels under low powers, a 20 per cent. solution of nitric acid is recommended by Osmond. For alloys in general, such as the copper tins, the bearing metals, etc., a dilute solution of nitric acid (1 per cent.) will be found to work well; but for alloys which contain much copper or other metal which is comparatively lightly attacked, such as the gun metals, aluminum bronzes, etc., a more or less strong solution must be used.

Heat tinting, first used by Behrens and Martens, gives very beautiful color effects, which depend upon the formation of films of oxides. The films form at different rates for different constituents. Heycock and Neville have used it with great success, as their papers on the effects of quenching alloys of copper and tin clearly show. Stead has designed a small electrical device for heat tinting, which can be performed by this means upon the stage of the microscope itself. He has obtained some wonderful results

in the case of the alloys of iron and phosphorus.* Heat-tinting does not, as a rule, show up the granular structure, especially that due to differences of orientation; but it is the very best means for showing the different constituents. As it does not remove any metal, the surface always remains flat, and the specimen is less liable to rust than in the case of acids and other reagents.

To preserve specimens from oxidation, etc., the simplest way is to cover the surface with a film of oil. This has the disadvantage, however, that the specimen must be cleaned each time before examination. Le Chatelier recommends that they should be varnished with "Zapon," a solution of gun cotton in amyl acetate. It is transparent and the specimens can be examined under the highest powers.

If we are studying a series of alloys it is often necessary to prepare a large number for fear of overlooking of some slight but important change. A preliminary examination embracing the whole series can be made upon one alloy, as pointed out by Le Chatelier. His results were obtained by superposing the two metals so that they mix only in the vicinity of their contact. A vertical section can be taken through the whole mass and the metals examined alloyed in all proportions from one pure metal to the other. This superposition is very difficult to obtain and often takes quite a while to perform successfully; in fact, in some cases, for example where a combination occurs heavier than the heaviest metal, it is impossible to get correct results. In the case of the brasses and the bronzes it yields excellent results.

When dealing with soft metals and alloys it is extremely difficult to obtain a good surface for microscopical examination, because in the process of polishing, the whole of the metal or alloy is not removed; part of it spreads as a thin film over the surface of the specimen and hides the structure beneath. In the case of slowly cooled specimens I believe Le Chatelier has tried to obtain a good surface by inserting a vertical strip of glass reaching almost to the

---

**Journal Iron and Steel Institute*, 1900, No. II.

bottom of the crucible, thus dividing the whole into two parts.

In the case of cast metals and alloys, Ewing and Rosenhain* have obtained some excellent results by casting upon plates of glass or of highly polished steel. They found, however, that the glass was very liable to break. If this happens before the specimen is solid, or rather whilst there remains any liquid in contact with the glass, we find part of it running through the cracks produced in the glass, thus spoiling the surface.

Mr. H. J. Hannover† has overcome this difficulty by casting upon mica. He cuts a funnel out of a piece of charcoal, places it on top of a fresh surface of mica, and then pours in his alloy. As this does not always give good results, he casts a small mass of the alloy upon the mica. The alloy thus obtained he places upon another sheet of mica and covers with some potassium cyanide. He then heats it by means of a blowpipe, and when the melting point is reached, places upon it another sheet of mica, previously heated, which he presses down till the alloy is solid. In this way he obtains a very smooth surface on the upper part of the alloy. I have seen this method of casting upon mica in use at the Royal Mint, London, where Roberts-Austen has obtained some very beautiful results.

When casting small ingots of an alloy it is often possible to obtain a clean surface by skimming the metal as it leaves the crucible with a stick of charcoal, retaining any oxides in the pot. On solidification, if this surface be examined, many beautiful and characteristic structures will be met with, and these are often an indication of the internal structure of the alloy.

MICROSCOPIC EXAMINATION.

There are so many papers and books upon the microscope that it will only be necessary here to describe those parts which are more or less peculiar to micro-metallography.

---

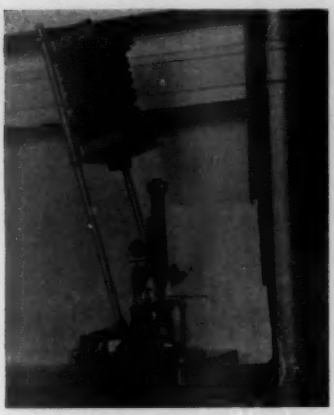
* Royal Society Proc., 1899, p. 85.

† *Bull. de la Soc. d'Encouragement*, August, 1900.

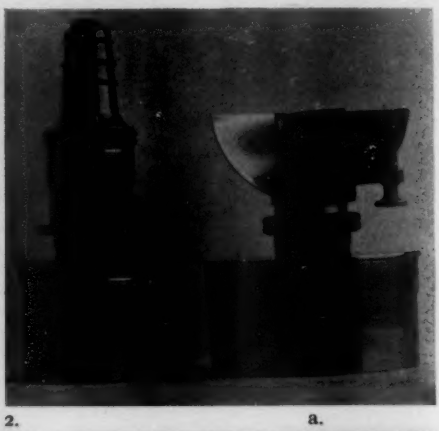
In the first place the stage ought to revolve so that differences in orientation can be observed. It is also very advantageous to have a stage which can be so adjusted that the axis of the microscope is normal to the surface to be examined. This can be effected by means of three leveling screws. Some specimen holders answer this purpose.

The next matter of importance is illumination, which is obtained by means of reflectors. For low-power work, using a 1 inch objective, the Sorby-Beck illuminator or reflector is the best (*Fig. 2, a*). It fits upon the objective. With it oblique and vertical illumination are obtained. To obtain oblique illumination the small mirror, with its face at 45° from the vertical, is turned out of the way. Then the horizontal rays of light are reflected at all angles except vertical upon the surface beneath (provided it is flat and the axis of the microscope is normal to it), and this surface appears dark. Irregularities in the surface will stand out sharply. For vertical illumination the small Sorby mirror is turned into place, and rays of horizontal light falling upon this mirror are reflected vertically upon the surface of the specimen and thence vertically up the tube of the microscope. Horizontal surfaces will therefore appear bright and irregularities will be dark. Vertical illumination for low powers can be simply obtained by a device invented, I believe, by Stead. A small cover-glass is fixed on a glass slide at 45° by wax or cement, and a piece of black cardboard or smoked glass fixed behind it in the vertical. Horizontal rays are reflected just as in the case of the Sorby illuminator; but as they can pass through the cover-glass, this method is rather better for powers below 1 inch, for the Sorby mirror, being attached to the objective, is comparatively far from the specimen.

For high-power work, using higher powers than 1 inch, the Beck illuminator answers very well. In *Fig. 2* the short cylinder contains a small disc of glass; light enters through the circular opening at the side. The illuminator is fixed between the objective and the tube of the micro-



1.

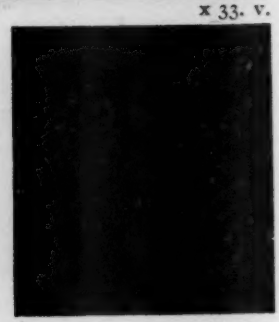


2. a.

3. x 33. v.

4. x 33. v.

5.



6. x 33. o.

7. x 33. o.

8. x 33. o.

scope. The disc of glass is set at an angle of 45°, and so light is reflected down the tube, through the objective and onto the specimen. This gives vertical illumination of course. When working with several powers, a multiple nose-piece or a Zeiss objective slide saves much time.

For high powers prism illuminators are also used; these fit between the objective and the microscope tube and work like the Beck. Stead recommends that made by Nachet. He uses the Sorby-Beck with a 1 inch objective, a Nachet prism with the $\frac{1}{4}$ or $\frac{1}{8}$ inch, and the Beck with the $\frac{1}{8}$ inch or $\frac{1}{16}$ inch oil immersion.

For illumination, an incandescent Welsbach light answers well for low powers, and for high powers an arc lamp gives the best results. Bull's eye condensers are generally necessary for all work: A small acetylene lamp has found favor with many workers.

For photographing the object, two methods can be used. In the first case the camera and microscope are vertical, whereas in the second they are horizontal. They both have their advantages. When vertical, it is comparatively an easy matter to place your object; when horizontal, it has to be firmly fixed. But with the vertical method the bellows of the camera must be restricted as to length unless you wish to use a step-ladder, or have your dark slide-holder and focussing glass in the room above; whereas, in the horizontal method, the bellows can be of great length and the magnification proportionately increased.

It is really a matter of taste which to use. Stead uses the vertical method, Roberts-Austen the horizontal.

Fig. 1 shows the apparatus used in Professor Howe's laboratory; it is manufactured by the Bausch & Lomb Optical Company and can be used in either position.

The method used by Le Chatelier is fully described in January impression of *Metallographist*, 1901, p. 10.

To any one interested in the details of practical metallography a paper by Stead will prove of great value. It was a lecture delivered to the Cleveland Institution of Engineers in February, 1900. It is reprinted in the *Metallographist* for

July, 1900. Papers by Le Chatelier,* Charpy,† Osmond,‡ Sauveur§ and many others go into the various details so thoroughly that any one can learn with a little patience the art and practice of the science. To those whose time is too fully employed to allow them to read all papers on the subject in the original, Sauveur's journal, the *Metallographist*, will give all that is necessary to follow the subject thoroughly.

THE CRYSTALLINE STRUCTURE OF METALS.

In the *Annales des Mines* for January, 1900, Osmond published a paper on the crystallography of iron, with some very beautiful illustrations. He concludes that iron in its three states crystallizes in the cubic system, but whereas, Gamma-iron crystallizes generally in octohedra, Beta- and Alpha-iron both crystallize out in cubes. In a later paper written in conjunction with G. Cartaud,¶ he confirms his previous results by causing the three allotropic varieties of iron to crystallize out as pure as possible, and at that temperature in which each variety is normally stable, the conditions being such as to allow free development of the crystals, the external forms remaining unaltered by the internal changes which might occur during subsequent cooling. The experiments were conducted in a porcelain tube, internally varnished, placed in a Mermet furnace. A Le Chatelier pyrometer was used to ascertain the temperature, which could be regulated by the gas supply.

Alpha- and Beta-irons were prepared by Péligot's method,‖ which consists in reducing ferrous chloride by hydrogen; whilst Gamma-iron was prepared by the method used by Poumarède,** in which zinc vapor replaces the hydrogen for the reduction of the ferrous chloride. Since the sur-

**Revue Générale des Sciences*, January, 1897; *Metallographist*, Vol. IV, No. 1.

† *Bull. Soc. d'Enc.*, March, 1897.

‡ *Rapports de la Commission des Méthodes d'Essai*, Vol. II; *Metallographist*, Vol. III.

§ *Metallographist*, Vol. IV, No. 4.

¶ *Annales des Mines*, August, 1900.

‖ *Comptes Rendus*, Vol. XIX, p. 670, 1844.

** *Comptes Rendus*, Vol. XXIX, p. 518, 1849.

rounding atmosphere has some influence on the results obtained, some Gamma-iron was prepared by the Péligot method and some Alpha- and Beta-iron by the Poumarède and the results compared. The paper is full of beautiful photographs and drawings, showing the various forms of crystals obtained. In many cases the crystals shown are identical in form with those prepared at South Kensington by Dr. E. Ball, who distilled galena in a porcelain tube in vacuo.

Ewing and Rosenhain * have developed the crystalline structure of many of the softer metals by casting on glass or polished steel. On examining the surfaces thus prepared various crystalline forms can be clearly seen.

Another way of examining the structure of some metals and of demonstrating their methods of growth is by allowing part of the metal to solidify and then removing the liquid portion. The beautiful crystalline structure of bismuth is brought out in this way. If pure lead be melted in a crucible and allowed to solidify round the outside, by pouring out the whole of the liquid contents a beautiful dendritic structure is revealed. Many beautiful specimens prepared in the laboratory of Dr. Percy are now in the collection at the Royal School of Mines, London.

This dendritic growth of crystals in metals is of very common occurrence. In the case of iron, dendritic crystals often occur in the cavities existing in that portion of the large ingots which solidifies last. Professor Tschernoff has quite a large collection, some of which are about 2 feet long.† On examining the surfaces of small ingots of most metals (and many alloys) we see many good examples. Lead and tin show them. They stand out above the surface of the ingot because they have grown at the surface, and as the metal solidifies the mass contracts more or less, the molten part sinks and they are left standing out in relief. *Fig.* 9 shows such dendrites of cadmium, which have the appearance of six-rayed stars, symmetrically arranged about

* Proc. Royal Soc., 1899.

† *Metallographist*, Vol. III, No. 3, p. 199.

a hexagonal axis. From each axis grows a series of parallel branches, making an angle of 60° with that axis, and therefore parallel to the next adjacent axis. Between each pair of axes there is seen the beginning of another axis, thus adding to the hexagonal symmetry.

[*To be concluded.*]

THE TECHNICAL HIGH SCHOOL OF BERLIN.

Technical education in Germany, as is well known, has been developed to a standard of excellence far superior to that of any other of the great powers. The equipment is of the best; the curriculum is most extensive in range; the professors are the best procurable in the various subjects; and every inducement is offered to the pupils to become thoroughly intimate with certain phases of industry. Probably the Berlin Technical High School is the leading institution of this character in Germany, but it is only typical of similar institutions distributed over the German Empire.

At the Berlin school, in the chemical section alone there are six fully qualified professors for the following branches of this science: organic chemistry, inorganic chemistry, chemical technology, metallurgy, electro-chemistry and photo-chemistry.

Further, there are six lecturers for the following branches: chemistry of foods, including analytical and bacteriological methods; agricultural chemical technology (sugar, beer, spirits, etc.); vegetable and animal fats, oils, etc., investigation of mineral oils and naphtha products; designing of chemical works and plants; architectural chemical technology; physical chemistry; thermo-chemistry, etc. The comparatively new chair of photo-chemistry affords instruction in spectral analysis, general photography, photo-chemistry, photographic optics, and the construction of photographic optical instruments.

AMERICAN LOCOMOTIVES IN GERMANY.

An official statement recently published regarding the American locomotives purchased by the Bavarian state railroads declares that so far from being unsatisfactory, as various Continental papers have stated, the American engines have proven themselves in many respects distinctly superior to those manufactured in Germany.

AMERICAN COAL IN GERMANY.

News comes from Germany that American coal is not looked upon with favor by housekeepers and consumers in general. The reason is to be found not in the poor quality of the coal, but in the lack of knowledge of the Germans. The coal is so hard and the stoves so poorly constructed, that the condemnation is not to be wondered at. Despite these obstacles, Germany must now depend largely upon the United States for her supply of anthracite. Great Britain scarcely produces enough for her own consumption.

Mining and Metallurgical Section.

[*Joint meeting of the Section and the American Institute of Mining Engineers, held Wednesday, May 14, 1902, at the Manufacturers' Club, Philadelphia.*]

Steel Rails: Relations between Structure and Durability.

By Robert Job,
Chemist to the Philadelphia & Reading Railway Company.

An investigation was begun some time ago at the Test Department of the Philadelphia & Reading Railway, to determine qualities in steel rails which resulted in fractures or in relatively rapid wear in service, and to work out the means necessary to reduce these to a minimum.

In order to gain information, arrangements were made to have forwarded to us a section of each rail which fractured in track or which was removed owing to undue rate of wear, together with detailed data regarding it. Such examination and tests as were necessary to establish clearly the cause of failure were then made. A considerable number of rails which gave good results in service have also been tested in the hope of finding fundamental characteristics which might account for the durability or the failure, as the case might be. Also, in our regular rail inspections at the mills, sections representing various methods of manufacture have been taken, and particular attention has been given to investigation of differences between rails which failed under the drop-test and those which passed it successfully.

Results of previous work upon rails had gradually forced the opinion expressed by Sir Lowthian Bell,* that from the results of analysis of rails he could prove and disprove everything that could be said for or against any composition of a rail.

* London meeting American Society of Civil Engineers, 1900. *Trans. A. I. M. E.*, February, 1901. Wm. R. Webster.

We believed then, as we do now, that proper chemical composition is one of the essentials in obtaining the greatest durability in steel rails, but our work had confirmed that of others, which will be referred to below, in proving that physical character and structure have at least an equal influence upon the final outcome. Accordingly, we have not limited ourselves to determining chemical composition, but have tried in each case to ascertain the definite cause of the weakness, whether chemical or physical.

Up to the present time about 200 defective rails have been examined. In some cases complete chemical analyses have been made; in others the loose, coarse-grained fracture or other physical character—such as piping—showed the cause at a glance, and in still others a rather elaborate investigation was necessary to prove the matter to a certainty.

It is evident, of course, that condition and arrangement of track has an important bearing upon durability of rails, and this matter, as we all know, has been worked out exhaustively by Mr. P. H. Dudley.* Our experience, however, indicates that in the large majority of cases with normal track conditions, short life of rails is attributable to the character of the steel, and is seldom found where toughness, strength and solidity exist.

In a general way, the results of analysis in this investigation have merely confirmed the previous opinion, and have proved beyond question that specifying chemical composition alone ensures neither a durable rail nor often a bad rail. We found, however, from the start a marked difference in the structures, and note the following general characteristics in the rails which gave defective service:

(*a*) Coarse regular granular structure, *Figs. 1* and *8* (50 diameters).

(*b*) Excess of foreign matter, such as oxides, slag and enclosed gas, *Fig. 2* (reduced 50 per cent.).

Either characteristic resulted in relatively poor service.

On the other hand, in rails of the same general composi-

* *Bulletin International Railway Congress*, xiv, No. 6, June, 1900.

tion giving satisfactory service, we have found (*c*) a generally fine, interlocking, broken up, granular form, with

(*d*) Relative freedom from foreign matter and gas. *Fig. 3*, which will be referred to again, represents a coarse example of this finer structure, and *Fig. 4* shows a characteristic structure of the head, reduced 54 per cent., showing freedom from foreign matter.

Upon comparing the above results with those obtained in our mill inspections we found complete accordance, for the rails of the character *a* - *b* proved exceedingly fragile under the drop-test of 2,000 pounds falling 20 feet. A section of rail, *Fig. 2*, from center of head, gave an elongation of only 2 per cent. in a 2-inch section, with tensile strength of 118,000 pounds per square inch. The analysis of these rails varied from:

Carbon, ·55 to ·63 per cent.; phosphorus, ·075 to ·104 per cent.; manganese, ·75 to 1·20 per cent., and sulphur, ·034 to ·07 per cent.

In contrast with this, rails when of the structure *c* - *d*, with the above composition, showed a marked toughness under the drop-test, and rail *Fig. 4* stood fourteen blows of the drop without fracture, turning after the first and third blows, and successive odd numbers. The composition was: carbon, ·644 per cent.; manganese, 1·09 per cent.; phosphorus, ·081 per cent.; sulphur, ·076 per cent., and a test piece from a similar rail, center of head, gave an elongation of 13 per cent. in 2 inches, with tensile strength of 132,000 pounds per square inch.

These marked differences were not at all unexpected, for they simply confirm the work of others. Mr. J. E. Stead, for instance, says:* "It is clear that the junctions (of the grains) are a safeguard, and the more junctions there are, the more reliable will the steel be." And again,† "it would seem to follow, then, that the smaller and finer the grain, the safer the structure." This coincides with the researches of Brinell, Sauveur and others.

**Journal Iron and Steel Inst.*, 1898, No. 1, p. 178.
†*Journal Iron and Steel Inst.*, 1898, No. 1, p. 185.

Next, in order to find out how these results tallied with those of practical track service, we made a comparison upon a lot of about fifty rails which fractured in track, each having had a life of less than five years. They came from different points upon our lines, and had approximately the composition stated above. A number of different mills were represented, but all of the rails could be grouped under the head of "coarse-grained," or of "finer grain," and upon figuring the fractures in each class to a basis of equal tonnage during the five years, we found an average of fifteen fractures of the coarse-grained material to one fracture of the relatively finer-grained, and in each case of fracture of the latter, we found that the weakness was due to pipes in the steel—defective cropping. This comparison, of course, applies strictly only to actual fracture, but it is well known that the same conditions which here have produced fracture also contribute to rapid wear in service. Mr. P. H. Dudley states:* "As I have already observed, the most serviceable rails have a fine structure and small mineral aggregates, though in many cases the so-called chemical composition is identical."

In our own work upon bearing metals† we have invariably found these conditions true, namely, coarse grain and presence of foreign matter result in relatively rapid wear in service.

Turning now to the influence of mill methods upon the size of grain.

During the past ten years marked progress has been made in knowledge regarding the metallurgy of steel, and, thanks to the work of efficient investigators, the general relations between structure of steel and its physical properties are so well proven that cause and effect in many conditions of mill practice have become matters of definite certainty. The cause of coarse granular form is clearly shown in Prof. Sauveur's valuable papers of 1893 before the American Institute of Mining Engineers,‡ and of

* *Trans. A. I. M. E.*, 1893, xxiii, p. 651.

† *Jour. Franklin Inst.*, 1900, cxlix, p. 449.

‡ *Trans. A. I. M. E.*, xxii, p. 547.

1899 before the Iron and Steel Institute.* Proposition V of the latter states: "The higher the temperature above *W* from which the steel is allowed to cool undisturbedly the larger the grains," and Proposition VI, "The slower the cooling from a temperature above *W* the larger the grains." In other words, stopping thorough working of the steel while materially above the recalescent point, and allowing to cool slowly, can result only in coarse granular structure, and such structure, other things being the same, has been proved by Professor Sauveur,† Professor Martens,‡ Mr. C. H. Ridsdale,§ Mr. R. G. Morse,¶ Dr. Sargent,‖ and others, to lower elongation and reduction of area, and to lessen the general toughness of the steel. Professor Roberts-Austen, also, in summing up the results of the important investigation made by the British Government after the St. Neots disaster, concerning loss of strength in rails, states: "The character of the grain, therefore, affords valuable evidence as to whether the rail has been rolled at a suitable temperature. . . . The relative amounts of the pearlite and ferrite, as well as the relative dimensions of the respective granules, afford very valuable indications as to the qualities of the rail and its probable durability."**

It will thus be seen that the unsatisfactory results which our service tests show with this coarse granular structure are merely the natural accompaniments of such character, and the entire investigation proves clearly the immense practical advantage in the betterment of quality which is being derived from the researches of metallurgists and metallographists, especially during the past decade.

The mills have not been slow to recognize the need of

---

* *Jour. Iron and Steel Inst.*, 1899, No. 2, p. 195. *Metallographist*, ii, p. 266.

† *Trans. A. I. M. E.*, 1893, xxii, p. 556.

‡ *Mittheilungen aus den Koniglichen technischen Versuchsanstalten*, xiv, 1896, p. 89.

§ *Jour. Iron and Steel Inst.*, 1898, No. 1, p. 234; 1899, No. 2, p. 128; 1901, No. 2, p. 75.

¶ *Trans. A. I. M. E.*, 1899, xxix, p. 731.

‖ *Trans. A. I. M. E.*, Richmond meeting, Feb., 1901.

** English Govt. Report on "Loss of Strength in Steel Rails," 1900, p. 58.

fine-grained structure in the heavier sections, and during recent years great efforts have been made to effect the change, and much progress has followed. At first, attention was directed merely to the finishing temperature; that is, the temperature at which the rail came through the last pass, without particular regard to the initial temperature of the ingot or bloom. In fact, high initial temperatures tended to prevail out of deference to the rolls, especially where these were light, or where the power was limited, and under such conditions it became necessary to hold the rails before running through the last passes, in order to finish at the desired temperature. The result of this procedure, as pointed out by Mr. S. S. Martin recently,* was to produce a fine granular form to the depth to which the working of the steel extended during these last passes, or to a depth of from $\frac{1}{8}$ to $\frac{1}{4}$ inch below the surface of the head.

Our own studies had proved the correctness of this statement, and further showed that the size of grain at center of head was but little affected by such treatment, as shown in *Fig. 5* (50 diameters). A surface toughening resulted, which would be of temporary benefit only, and could hardly from its nature cause any very decided increase in durability in service. The character needed is not a fine-and-coarse irregular structure, but one fairly fine even at the center of head, and practically amorphous at the surface; just such a structure, in fact, as we find in the rails of lighter sections rolled before the heavier sections came into use. *Fig. 6* (50 diameters) represents the structure at center of head of a 67-pound rail which was rolled and laid in 1864, and which withstood thirty-four years' heavy traffic, and since then has been in use in side track. The analysis is:

Carbon	·33 per cent.
Phosphorus	·039 " "
Manganese	·390 " "
Sulphur	·030 " "
Silicon	·070 " "

Fig. 7 (reduced 64 per cent.) represents the appearance of this rail in 1898, etched, and shows that it had evidently been

* *Iron Age*, Dec. 26, 1901.

greatly worn from its original section, and contained a pipe in the web. The metal, however, has not "flowed over" upon the side of head, although the steel is comparatively soft. In explanation, however, it is to be noted that the head is almost free from foreign matter, and that the structure even at center of head is exceedingly fine.

"Flowing over" has been found by us to be practically independent of the composition, and caused generally by unwelded seams due to presence of foreign matter and gas in the steel. In 1890 Dr. C. B. Dudley stated* that his studies of such rails "would seem to indicate that disintegration or crushing of steel is largely a resultant of lack of soundness in the ingot, and is more mechanical than chemical, except in so far as chemistry may be responsible for the soundness of the ingot." In some cases, however, we have found almost complete freedom from unsoundness, but in each such instance a coarse granular structure was present. Mr. P. H. Dudley also states:† "The mineral aggregates are large and friable, and the surface of the rail breaks down more than $\frac{1}{32}$ of an inch in depth, readily flowing under wheel pressures." Thus, it seems clearly established that such condition may arise from marked weakness due to any cause, whether unsoundness of the metal; weak, coarse structure, or even such composition or form that the rail is unable to support the load and becomes flattened.

In the case of the 67-pound rail, *Figs. 6* and *7*, which gave excellent service, the composition is exceptionally free from defects. It is, however, a matter of common experience everywhere that the composition of these old rails of light sections is exceedingly irregular. As Captain Robert W. Hunt expressed it last year before the American Institute of Mining Engineers,‡ "they were high in carbon and low in carbon; high in manganese and low in that element; high in phosphorus and higher in phosphorus; but they all gave good service." One such rail taken from our tracks contained ·160 per cent. phosphorus with ·44 per cent. carbon,

* *Trans. A. I. M. E.*, 1890, xix, p. 893.

† *Trans. A. I. M. E.*, 1893, xxiii, p. 650.

‡ *Trans. A. I. M. E.*, Richmond meeting, Feb., 1901.

but still had given long service. The one characteristic common to all of these rails is that of fine granular structure; in fact, it was necessitated by the conditions under which they were rolled, for the steel was thoroughly worked well down toward the critical point.

In order to note the exact influence of structure upon quality, we took at random from a heat which passed the drop-test a rail having the following composition:

Carbon	·56 per cent.
Phosphorus	·102 " "
Manganese	1·08 " "
Sulphur	·056 " "
Silicon	·147 " "

turned down a section at center of head and obtained the following results:

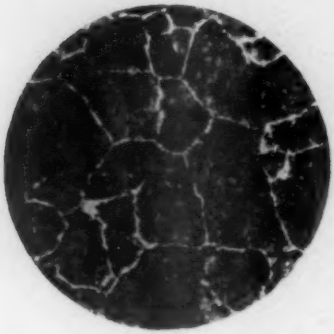
Tensile strength	128,400 lbs. per sq. in.
Elongation in 2 in.	8½ per cent.
Reduction of area	3½ " "

The structure (50 diameters) at center of head is shown in *Fig. 8*, and the etched head (reduced 50 per cent.) in *Fig. 9*. The former is very coarse, but the latter is tolerably free from foreign matter.

An adjoining portion of the same rail was then reheated to a cherry red, and let cool at once in the air. A test section was then turned from the center of head, having a structure (50 diameters) represented in *Fig. 10*, and gave the following results:

Tensile strength	129,500 lbs. per sq. in.
Elongation in 2 in.	12 per cent.
Reduction of area	10·1 " "

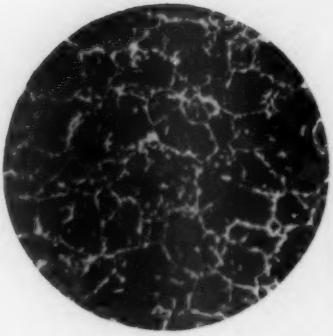
It is thus seen that the change shown in the structure has caused an increase of strength, an increase of nearly fifty per cent. in elongation, and an increase of nearly threefold in reduction of area, fully accounting for the marked difference observed in service between the coarser and the finer structures, respectively. As Mr. William R. Webster stated at the Paris Congress of the International Associa-



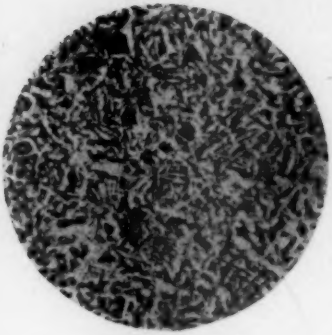
1

2

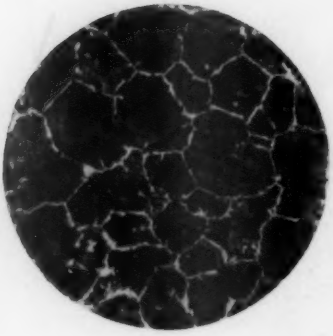
4



3



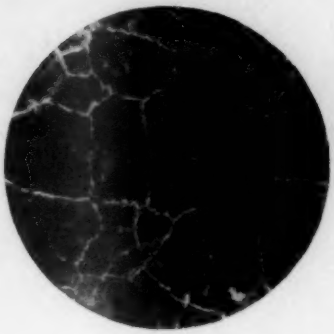
6



5

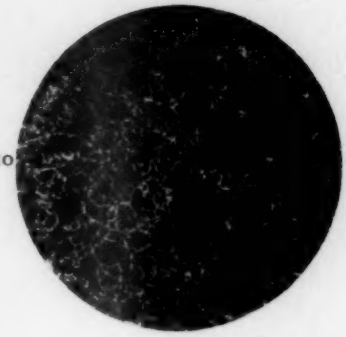
7

8

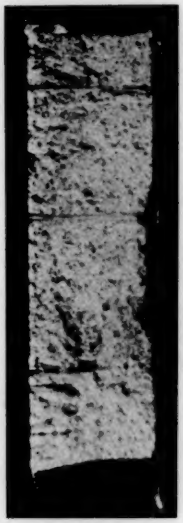


9

10

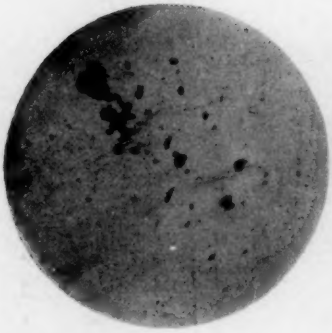


12



11

13



tion for Testing Materials, in 1900:* "The matter of vital importance is to work steel in such manner that it is not put in service with this coarse grain."

In the foregoing we have seen that coarse granular structure seriously weakens steel, and that brittleness under the drop-test is found when in addition the metal is "burned" or contains an excess of foreign matter. The result of a large number of tests further proves that fracture under the drop-test seldom occurs if the steel is homogeneous and free from unsoundness. In other words, mere ability of rails of this composition to withstand the drop-test is no guarantee of fine granular structure, and consequently other tests of quality are essential to necessitate durability. *Figs. 1* and *8* represent rails of coarse granular structure which passed the drop-test with good deflection, but such rails do not give satisfactory service.

The foreign matter and gas which produced brittleness was generally found in small cavities or lines scattered throughout the section, but especially prominent within ½ inch from the surface around the head, and caused a series of unwelded seams—elements of weakness. The appearance was usually similar to that of *Fig. 2*. Rails which did not fracture under the drop-test at the same rolling were found comparatively free from this enclosed matter around the outer portion of the head, though in some cases a considerable proportion was found nearer the web. Still, the solid band of homogeneous material around the outside of the head gave sufficient toughness to the rail to enable it to resist the force of the drop. It is of interest, however, to note that an excessive proportion of foreign matter and gas in rails may not cause failure under the drop test in cases where the grain is comparatively fine, since the strength incident to such structure may offset the weakness caused by the unsoundness. A typical case came under our observation not long ago. A lot of 90-pound rails had been rolled, and had passed the drop-test without a single failure, and the average structure was somewhat finer than that represented

* *Engineering*, August 10, 1900, p. 193.

in *Fig. 3*. After being in tracks for a few months a number of the rails began to flow over and break down under the heavy traffic to such an extent that replacement became necessary. Upon inspecting the track we found that some of the rails from the same rolling were in good condition, showing little wear, while others next to them were badly broken down, often along the entire length. The defective rails were not confined to any one heat, but were scattered throughout the rolling. Sometimes the outside edge of a rail was broken down, and sometimes the inside edge. Some in a given heat were showing good service, while one or more from the same heat were defective. Eighty-pound rails of practically the same composition had previously been in this track and had given good service, and had not been broken down by the same traffic.

In order to get at the cause of the difficulty, sections of some of the defective rails were obtained, and showed the following average composition:

Carbon	·544 per cent.
Manganese	1·005 " "
Phosphorus	·078 " "
Sulphur	·090 " "
Silicon	·120 " "

There was nothing abnormal in this, and many rails of essentially the same composition have given good results under heavy traffic conditions.

We next investigated the structure of the steel. *Fig. 12* represents the general character of the fracture magnified to 1½ diameters, and is a longitudinal section down through the head of the rail about ½ inch from the center line. The striations which appear are unwelded seams which break up the continuity of the steel and produce planes of weakness. In order to learn the extent of these defects, we polished off a full section of the rail and etched lightly with iodin, finding that the entire surface of the section was covered with lines of unwelded seams, as represented in *Fig. 11* (reduced 52 per cent.). Microscopic examination showed that the steel contained a large number of particles of foreign matter—*Fig. 13* (x 50 diameters)

—and that some seams were coated with blue and brownish films, evidence that the steel had been burned,* and fully accounting for the failure to weld. *Fig. 3* gives a section from center of head, and proves that the rail was worked and finished at a moderately low temperature, and that owing to the consequent fairly fine structure the rails withstood the drop-test in spite of the weakness due to defective manufacture. When laid in track, the weight of the rolling stock caused the unwelded seams to slip apart at the portions where the greatest strain came, thus resulting in the breaking down of the rails. The upper right-hand corner of *Fig. 11* shows where a sliver ½ inch thick was forced out of the side of the head along one of the unwelded seams for a distance of several feet, and the crack along the seam extended nearly to the top of the head.

This instance proved conclusively that reliance could not be placed upon the drop-test to ensure homogeneous, solid steel, and it is generally well known that rails of laminated steel may give even a better test under the drop than if composed of solid metal of the same composition.

The above results clearly verify the statement of Mr. P. H. Dudley † that solidity and continuity are quite as important as a good microstructure.

As to the origin of foreign matter in steel, it is evident that it must be due to defective mill practice either in the manufacture of the steel, including teeming and settling; in burning of steel in soaking pits—or in blooming furnaces, if the latter are used,—or in cropping blooms or rails; in any event, it is an unquestioned proof of defective mill practice, and is easily avoided if so desired.

In order to ensure the most durable rail of a given composition, our service results, as shown above, indicate that there must be—

(1) Freedom from brittleness.
(2) Absence of unsoundness.
(3) Fine granular structure.

---

* J. E. Stead: *Journal Iron and Steel Institute*, 1898, No. 1, p. 183.
† *Trans. A. I. M. E.*, 1893, xxiii, p. 652.

(1) Brittle rails are eliminated by the drop-test of 2,000 pounds falling 20 feet upon a rail-butt from the top of the ingot, one rail from each heat being tested, or, in case of fracture, two more being taken from the tops of other ingots of the same heat; fracture of two out of the three causing rejection of all rails in the heat.

(2) Absence of unsoundness is best ensured by careful inspection throughout the manufacture, and by specifying a definite proportion of cropping.

(3) Fine granular structure is necessitated by specifying, under definite conditions, the shrinkage of the rail after leaving hot saws—an idea suggested by Mr. Wm. R. Webster.*

A shrinkage limit is in operation in most of the mills to-day, but it must be borne in mind, as pointed out by Mr. Martin in the paper above referred to,† that specifying merely the distance between hot saws does not compel presence of fine grain clear to center of head. Such structure will not result unless the reduction in the passes after the holding is sufficient to work the steel thoroughly to the center.

What is needed is a moderately low initial temperature, sufficient work to render the steel solid, the speed of train and extent of reduction being such that with rapid rolling—without undue holding before or in the last passes, and without artificial cooling subsequently—the distance between hot saws shall not exceed a specified amount.

Under the above conditions, with a given composition, the extent of shrinkage of the rail after leaving hot saws may be made a definite guarantee of size of grain in sections of a given weight, and if the limit is placed at 5½ inches for a 30-foot length of a 90-pound rail, coarse grain even at center of head is practically impossible.

It is, of course, obvious that mere fine grain does not render certain freedom from brittleness, as, for instance, in the case of the St. Neots rail above referred to,‡ where the steel

---

* *Engineering*, August 10, 1900, p. 192.

† *Iron Age*, Dec. 26, 1901.

‡ Page 21, above

was fairly fine-grained, but was fragile owing, it is said, to presence of martensite due to rapid cooling from a high temperature. Such composition was, however, evidently caused by a very exceptional accident in mill practice, and is carefully guarded against under normal conditions.

In working toward the most efficient practice in rail rolling, valuable aid has been given during the past few years by Committee No. 1 of the American Section of the International Association for Testing Materials, and Mr. Wm. R. Webster, the chairman, deservedly receives great credit for his efforts in bringing together the various conflicting interests, and in formulating proposed standard specifications of various materials of construction. The specifications for steel rails in particular have aroused wide discussion. In its present form we regard it as tentative, since it merely specifies the quality which, since the introduction of the heavier sections, has everywhere been found rapid wearing and unsatisfactory. It does not ensure durable material, and it does not represent the best American practice. It will, however, serve as a basis to which the necessary additions or modifications can be made, and also its effect in provoking discussion will be of assistance. If so drawn as to represent the best American practice, it would benefit the railroads as a class, and would undoubtedly be of great commercial value to the mills as an influence upon foreign orders, and would go far toward proving that many rail failures and cases of brittleness attributed abroad to chemical composition have been simply results there of defective mill practice which would not be found under the given best American practice. As an instance, we may cite the statement of Mr. C. P. Sandberg before the International Railway Congress in 1901,* that he made some experimental tests with rails containing up to ·60 per cent. carbon, and met with complete failure. The rails were brittle, and broke under a drop-test of 1 ton falling 10 feet. The carbon ranged from ·56 per cent. to ·62 per cent. In

* *Bulletin International Railway Congress*, English Ed., xv, p. 1647, July, 1901. Also *Jour. Iron and Steel Inst.*, 1898, No. 2, p. 78.

contrast with this we have the regular practice of our American mills, where, as shown above, failure under the drop-test of 2,000 pounds falling 20 feet seldom occurs, even with carbon considerably beyond the ·60 per cent. limit, provided proper care is exercised in manufacture.

The specifications proposed to the American Railway Engineering and Maintenance of Way Association* are an improvement over those of the International Association in inserting a shrinkage clause, but the wording of the latter is open to the objection cited by Mr. Martin,† and would ensure merely fine-grained material upon the immediate outer surface of the rail.

Every successful specification is of necessity based directly upon the teachings of actual service. In order, then, to aid the mills in working out the most efficient standard practice, it is greatly to the interest of every consumer to make known the practical service values of the various materials. Our object in entering upon this investigation has been, naturally, to secure the greatest degree of safety and durability in the tracks of the Reading Railway, but we have brought the results to your attention in the hope that a full and free discussion of facts may be of general benefit in tending toward the production of uniformly durable material.

In conclusion, I wish to thank my assistants for the analytical and inspection work carried on in connection with this investigation.

READING, PA., May 15, 1902.

EXPLANATION OF PLATES.

Fig. 1.—x 50 diameters. Center of head. Coarse open grain which wears rapidly in service.

Fig. 2.—(Reduced 50 per cent.) Foreign matter which causes brittleness.

Fig. 3.—x 50 diameters. Finer granular form which gives much better service than *Fig. 1.*

Fig. 4.—(Reduced 54 per cent.) Freedom from foreign matter.

Fig. 5.—x 50 diameters. Center of head. Rail held before last two passes.

---

* *Amer. Railway Engineering and Maintenance of Way Asso. Bulletin*, 22, March, 1902.

† Above, pages 22 and 28.

Fig. 6.—x 50 diameters. Center of head. Very durable and slow wearing. Thirty-four years of hard service.

Fig. 7.—(Reduced 64 per cent.) Homogeneous head. Rail, *Fig. 6*, after thirty-four years' service.

Fig. 8.—x 50 diameters. Rapid-wearing rail, stood drop-test.

Fig. 9.— Reduced 50 per cent.) Foreign matter in *Fig. 8*.

Fig. 10.—x 50 diameters. Center of head. *Fig. 8* re-heated.

Fig. 11.—(Reduced 52 per cent.) Mashed down in track after six months' wear.

Fig. 12.—x 1½ diameters. Fracture of *Fig. 11*, showing unwelded seams.

Fig. 13.—x 50 diameters. Oxide spots in *Figs. 11* and *12*, preventing welding.

[*To be concluded.*]

STATISTICAL REVIEW OF THE ELECTRO-METALLURGICAL INDUSTRIES OF GERMANY; DEPOSITION OF ZINC.

There are four sodium plants; two use the Castner process; two the Rathenau and Suter process; one plant makes sodium for the production of cyanides and sodium peroxide, caustic soda being the raw material. There are seven copper works; the total copper production of Germany has increased from 24,700 to 32,000 tons in the last ten years. Some interesting notes are given concerning the Papenburg works; while it has been generally supposed that the Hoepfner copper process is there in extensive use, it is said that only a small quantity of copper is produced there at present, and that probably the production of copper at that plant will be given up, "because copper-nickel matte is not available;" the original Hoepfner process, as it has been used in the Weidenau trial plant, is described in detail; the process is said to have been modified later. The Elmore process, in use at Schladern for making copper tubes, is said to have reached remarkable perfection. At a Hamburg refinery about 3,000 kilograms of fine gold are produced yearly by the Wohlwill process, the anodes being of raw gold, 980 fine, with impurities of platinum and silver; from the sludge about 12 to 15 kilograms of platinum are obtained. Besides this, still greater quantities of Transvaal gold, down to 850 fine, are electrolytically refined. The electrolytic zinc industry is still in its infancy; in most works the operation has ceased. Some interesting remarks are made on the electrolytic deposition of zinc from solutions. The deposition of pure solid zinc is impossible, if the solution contains many impurities. Zinc is more electropositive than hydrogen and can be obtained from neutral or slightly acid solutions only for the reason that a higher E.M.F. is required to make a hydrogen ion give off its charge at a zinc electrode than at an electrode of most other metals (which evidently means, on account of the "Ueberspannung"). If the solution contains impurities of metals which are more electronegative, these are preferably deposited with the result that the cathode is then no longer pure zinc, but is mixed with other metals by which a hydrogen ion gives off its charge more easily than a zinc ion. The most dangerous impurity is iron. In reference to the troubles in the analytical examination of zinc by electrolysis

if iron is in the solution ; as long as there are much more zinc ions than iron ions, zinc is deposited ; but when the ratio of the number of iron ions to that of zinc ions reaches a certain value, iron is deposited together with the zinc ; the cathode then contains iron, and at this iron hydrogen ions can give off their charges more easily than zinc ions ; zinc is dissolved with vivid development of hydrogen and disappears from the platinum pan. This is brought into connection with the influence of current density upon the form of the zinc deposit. When a pure zinc salt solution is electrolyzed with a pure zinc cathode, zinc is deposited and hydrogen appears only at very high current densities. If, however, the solution contains iron ions, iron is deposited preferably, and at the ion deposit, thus formed, hydrogen gives off its charge preferably at low current density, and hydrogen together with zinc at medium current densities. If, however, the current density is great enough, the small iron particles on the cathode are quickly covered with zinc, so that the cathode becomes again pure zinc and no hydrogen is given off ; only at very high current densities are zinc and hydrogen again deposited simultaneously. This may be the reason why from pure solutions a good zinc deposit is obtained at low and medium current density, and spongy zinc at very high current densities ; on the other hand, from impure solutions as they exist in practice, spongy zinc is obtained at low and very high current densities, and a good zinc deposit at medium current densities.—*Zeit. f. Elektrochemie*, through the *Electrical World.*

MICA SPRINGS.

The *American Machinist*, of recent date, says : "Mr. W. C. Leland, a machinist of Brooklyn, referring to our inquiry some time ago for a spring made of a substance which would not be affected by heat, sends us some pieces of mica arranged to act as a flat spring, and he says that a mica spring continues to act as a spring when exposed to very high temperatures. A specimen he sends us acts as a spring when held in a gas flame and continues to so act for a considerable time—at least as long as our patience has held out to test it. Of course, as many layers of mica may be superposed as is necessary to get the desired thickness, and for experimental purposes at least we would imagine that such a spring may be quite useful."

HIGHER SPEEDS ON RAILWAYS.

Efforts to attain higher speeds upon railways, both steam and electric, have not yet met with much success; the latest electrical railway, that of the Berlin-Zossen line in Germany, having failed to reach the hopes of its projectors. It was planned to run trains at a velocity of 125 miles per hour, but it has been abandoned when only 100 miles per hour was reached for a short distance. The facts are that there are no precedents for the task that was undertaken in the Berlin-Zossen enterprise, and all sorts of obstacles were encountered at the start, the principal one being that, even in its brief existence, it was found impossible to maintain a safe track, and this upon a practically straight line. Steam railways, with the most powerful locomotives of modern build and only two-car trains, cannot get above seventy miles an hour for runs under 100 miles.

Haupt's Reaction Breakwater.

[*Being the report of the Franklin Institute, through its Committee on Science and the Arts, on the invention of Prof. Lewis M. Haupt. Sub-Committee: Ambrose E. Lehman, Chairman; John Haug, Louis E. Levy.*]

HALL OF THE FRANKLIN INSTITUTE,
[No. 2163.] PHILADELPHIA, December 5, 1900.

The Franklin Institute of the State of Pennsylvania for the promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the merits of Haupt's Reaction Breakwater, reports as follows:

This invention consists of a method and means of application whereby channels opening in tidal waters may be made practically navigable for vessels of deep draft, and requisite depth maintained by the operation of natural forces alone, and without continued dredging.

The inventor's work includes an extended investigation of the natural laws controlling the formation of harbor-bars, sand spits and other physical features composed of littoral drift on alluvial coasts, and a determination of the data relating to these subjects.

The invention is submitted to your committee in the developed form which it has taken in the course of experience since its first introduction by the inventor, thirteen years ago. At various stages during this interval, the subject has received the consideration of a number of scientific bodies and of eminent maritime engineers, and the theories of the inventor, approved in these discussions, have been further elucidated by the official surveys and charts of the United States Coast and Geodetic Survey, and of the United States Engineers in charge of harbor improvements.

In the year 1887, the American Philosophical Society, after a careful investigation of Professor Haupt's Reaction Breakwater System, through a committee of its members, conferred upon him the Magellanic premium and gold medal for his masterly presentation of this subject in a paper

under the title, "The Physical Phenomena of Harbor Entrances; their Causes and Remedies and Defects of Present Methods of Improvement." This paper was published in the proceedings of that society in 1888, and the report of the committee is on file in its archives.

For three models illustrative of Aransas Pass, Texas, and its conditions as a port of entry, with plans for its improvement, exhibited at the National Export Exposition of 1899, Professór Haupt was awarded the highest premium, a silver medal and diploma. At the Paris Exposition of 1900 a similar exhibit, consisting of models and plans for the removal of ocean-bars and alluvial obstructions in the paths of navigation, and for the improvement of the South West Pass of the Mississippi River, by a reaction jetty or breakwater, was awarded a gold medal and diploma. The members of the jury of awards were men most prominent in their profession and well qualified to judge matters of this nature.

In October, 1899, Professor Haupt's methods and inventions were the subject of earnest and exhaustive discussion in the American Society of Civil Engineers by some of its members of large experience as maritime engineers. On this occasion they bore a very searching analysis and received a favorable verdict based upon facts proceeding from actual tests of the theory of the Reaction Breakwater or single-curved jetty.

Heretofore it has been extensively the practice to construct jetties or breakwaters in pairs, so placed that the ebb currents thus confined in a constricted passage may cause an increased scour, and when in any case the full results are not attained, spur jetties projecting from the main jetties towards the center of the channel are added to increase the contraction.

These methods do not as a rule serve their purpose to a satisfactory extent, and in many instances constant dredging is required to keep the channel open. To the cost of construction of the two jetties must therefore be added that of maintaining the required depth of water by auxiliary means.

The purpose of the applicant has been to simplify and render more effective and economical the methods of securing and maintaining navigable channels over or through ocean bars. Few men with the ability to work out these problems would have had the intrepidity to undertake so formidable a task, involving as it did long periods of investigation and study in field and office, over a wide range of physical phenomena, most obscure and difficult of access. That his theoretical conclusions have been practically verified is exemplified at Aransas Pass, Texas. Here the natural conditions and forces were carefully studied and most effectively applied by the use of a single detached curved breakwater designed on this system, although the structure is not yet fully complete to the extent of the original plans. This example consists of a single jetty in the form of a compound and reversed curve placed to "windward" of the navigable channel and generally in line with the natural trend of the currents. An open space is left between the shore and the head of the jetty to admit the flood tide freely. This opening changes the conditions of equilibrium between the flood and ebb movements in such a manner as to cause a larger volume of the ebb currents to pass over a contracted section of the bar, and thus scour out the channel. Such, briefly described, is the Reaction Breakwater at Aransas Pass. The depth of water over the bar has been materially and progressively increased by the utilization of the natural forces only and is maintained without interruption.

The increasing size and draft of vessels call for depths of channels of not less than 35 feet, and experience has abundantly proven that the methods in most general use are inadequate to create or maintain these necessary channel dimensions without great expense.

In applying the general principle involved in the Haupt Reaction Breakwater, the conditions to be fulfilled may be briefly summarized in the order of their relative importance, as follows:

(1) To arrest the littoral drift before it reaches the channel.

(2) In sea-coast inlets, to permit free ingress of the flood tide by placing the work so as to interfere as little as possible with its entrance.

(3) To so adjust the plant that the spreading of the outflowing waters over the outer area may be confined to a single channel across that section of the bar where the external forces are weakest.

(4) By thus changing the conditions of equilibrium the efflux currents may be made to produce a local excess of energy in favor of the ebb movement.

(5) The effect of the curved breakwater is to produce a continuous reaction entirely across the bar, thus causing counter currents which will erode the bottom of the channel and convey the silt to the convex side of the entrance.

(6) By this means the extension of the bar seaward is prevented and a counterpart of the jetty is produced on the opposite bank of the channel without expense, this counterspit automatically adjusting itself to the local requirements.

(7) As the construction of one breakwater is thus required, instead of two, and as its length is less than half of that of the parallel jetty system, the expense of the work will be proportionately less.

(8) The desired result is also secured in much less time than by former methods, because of the more rapid erosion of the channel. This process is furthered by the utilization of the forces of gravity as well as of impact and momentum to cut away the bar, thus reducing the necessity of dredging and possibly dispensing with it altogether.

(9) It naturally follows that a channel produced by utilizing the forces of the current will be, in a large measure, self-sustaining so long as the conditions that cause it are effective.

(10) As the channel is thus formed by the natural forces and currents and therefore adapted to their conditions, no injury can result to the stream, pass or inlet from excessive contraction, as has sometimes happened from parallel and spur jetties.

For further and more minute detail concerning the features and merits of the Haupt Reaction Breakwater

System, reference is directed to the letters-patent (No. 380,569, of April 3, 1888) and to the publications of the American Philosophical Society; the American Society of Civil Engineers; the *Journal of the Franklin Institute;* the report of the judges of the National Export Exposition, and the official reports of the United States Coast and Geodetic Survey and of the United States engineers in charge of harbor improvements.

In recognition of the scientific research and practical efforts which have culminated in the invention and demonstration of the Reaction Breakwater, and of the economies to commerce resulting therefrom, the Franklin Institute bestows the highest award within its gift, the Elliott Cresson Medal, upon Prof. Lewis M. Haupt, the inventor of this system of harbor improvement.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, January 2, 1901.

Attest: WM. H. WAHL, *Secretary.*

APPENDIX.

REPORT OF THE COMMITTEE OF JUDGES OF THE NATIONAL EXPORT EXPOSITION, CLASS 40, ON THE SUBJECT OF THE CLAIM OF PROF. LEWIS M. HAUPT FOR HARBOR IMPROVEMENTS BY MEANS OF A REACTION BREAKWATER.

Directly opposed to the popular belief that everything is formed by nature for the express needs of man, investigation finds one of its most flagrant contradictions in the fact that, although man is commercial by instinct and education, harbors may be absent over long stretches of coast, or that they may be so poor as to make the intervention of man necessary for their improvement and maintenance. Maritime engineers, however, fully recognize these to be facts, and are sedulously engaged, the world over, in seeking to rectify, or at least to ameliorate, defects in conditions which they cannot create.

Of all opportunities offered in this direction, none are so great as those involved in the betterment of channels passing through alluvial shores directly to the sea. As to those channels, one should suppose that, from careful study, it would be clearly seen by all, what nature, through the constant exercise of her functions, points out as the best methods by which her forces can be directed towards the modification of what she has not, for man's special needs, accomplished at first hand

as the best attainable results. For the plainest possible instance of the natural conditions which point the way towards the betterment of such alluvial channels, we cannot have a better illustration than that afforded by the shores of the United States from Sandy Hook to the Rio Grande and beyond. Along these is to be seen a continental belt of narrow islands, once shoals, afterwards spits of sand, and now, with the breaks between them, called inlets, a nearly continuous breakwater against the encroachment of the sea. Back of this long line of outworks of the continental shore, therefore, lie bays of greater or less area, drained by these inlets.

The nearly continuous breakwater formed by these narrow islands would be actually continuous but for the fact that the bays, as well as the sea, perform a function in the details of this sort of construction. They and the sea together determine the particular points where the inlets draining bays shall be. Through their instrumentality, in conjunction with that of the sea, are moulded all the details relating to the trend and general character of all fringed coasts of this kind. By the sea is to be understood all that relates to it as the all-embracing factor in one set of effects produced, just as by the land is to be understood the other factor, whose all-embracing agency contributes by another set of effects to the resultant. In a word, we have, in the formation of such alluvial basins and inlets as are here under consideration, results from which the character and amount of energy of nature at each point is clearly recognizable. That is, one can, through careful study of the physical actions involved in the problem, not only distinguish their respective operative causes, although compounded, concerned in the production of the final physical event. And it is obvious that, if man is able by study to recognize clearly the elements of causation in this case, to form a correct diagnosis of it, he should be able artificially to better the physical conditions, by which they are represented, through modes of working hand in hand with nature, as elsewhere in mechanics, for the transmission to the best advantage of her energy.

Any main coast is chiefly determined geologically by vertical forces, and in a case of the kind under consideration, is topographically modified by the influence of the land and of the sea, through its winds and currents and waves acting upon material light enough to be held in suspension during longer or shorter periods of transportation. Notwithstanding that the rise and fall of the tide on the Florida Reef is between 1 and 2 feet, and, therefore, any possible current superinduced by it in the narrowest inlet between Keys is necessarily far from swift, the waters of the inlet on each side of Key Biscayne may sometimes be seen to change within a few minutes from crystal clearness to milky whiteness, from the inflow of current there, due to the rise of the tide generating current passing through the inlets and transporting

minute particles of disintegrated coral to add to the elevated marl-beds of Biscayne Bay. What is so evident to the eye in this case, on account of the whiteness of material borne in suspension in the water, occurs also in other cases where silicious sand is the burden of the water; for where currents are stronger than here, they scour muddy, sandy, and other bottoms, and the sides of the channels, with strength proportional to their velocity and volume—to their momentum. The most careless observer of sandy beaches takes notice that the waves, beating on the shore with violence, churn up particles of sand and other detritus, and that these are borne off by currents for longer or shorter distances, and that even the tiny ripple disturbs some sandy shores, and leaves its trace in sand transported and deposited in serrated lines for distances representing the force of the impact of the water, or with the current sent for greater distances in long smooth stretches far along the shore.

The most primitive of all methods that can be conceived of for establishing an effectual channel for efflux and influx of water along such coasts as these we are considering is to build two parallel, or approximately parallel, jetties passing outward from an inlet to the sea, regardless of the prevalent winds and currents of the region, and periodically to dredge out the sediment accumulated between them. If it were the best plan, it would also be the most expensive; but it is the worst. The current from the rising tide is sometimes flowing into the sea-opening between the jetties at times when the current from the bay is seeking egress. Even supposing the impossible case, of freedom of flow in both directions, coincidently with change of tide, no more water can obtain entrance for inflow than for outflow; whereas, what such channels need is preponderance of outflow for scouring purposes. Such constructions have been made along our coast, open to the prevailing drift of the region, or a single submerged spur-jetty has been placed in a similar position, athwart a channel. Thus is ensured, in the first case, speedy resort to dredging, in order to keep the channel free, and in the second, gradual submergence of the whole work in the sand. The first of the two projected jetties, intended to be protective of a channel, has actually been built to leeward of it, with what should have been the obvious consequence of the injury of the channel which it was the main object to conserve and improve. The two parallel jetties at the mouth of the Mississippi, the great engineering work of Captain Eads, are not in the same category with such works. The body of water represented by the Mississippi is a *vis viva*, a living power of great strength, having no dependence for energy upon current formed by rise and fall of tide. It rolls resistlessly in one direction, acting as a huge tool graving its way through the muddy bank which the waters of the Mississippi have through the centuries deposited in the tract known as its delta.

We Americans hold ourselves as a people intelligent and far-seeing

beyond any other nation of the earth, and yet it is thirteen years since the true method for treating certain of our Southern inlets was crowned, without adequate practical results, by the American Philosophical Society, and its discoverer has not yet been able to obtain, from the millions yearly disbursed by the Government on harbor improvements, a fair opportunity to demonstrate what some of the most experienced maritime engineers of the day regard as a great discovery. To give some idea of the difficulty which this inventor, Prof. Lewis M. Haupt, has encountered, it is only necessary to quote the concluding sentence of the Board of Engineers, U. S. A., in rejecting Professor Haupt's plan as of no value. "The views," it says, "are purely theoretical, are unconfirmed by experience, and contain nothing not already well known, which has a useful application in the improvement of harbors." This verdict is so self-contradictory, implying that there are in the views presented things that are well known as useful in the improvement of harbors, and yet explicitly stating that those views are purely *theoretical*, that one's faith in the carefulness of the examination by which the conclusion was reached may well be shattered. To cap the climax, an officer of the U. S. Engineers has stated that methods such as those recommended by Professor Haupt had been tried without success in several places; but examination shows that the trials were either half experiments, or else, through inappreciation of the conditions precedent to success, were wholly misdirected.

Among other maritime engineers, however, who have examined into the jetty system of Professor Haupt, there is hardly a dissentient voice as to the value of his discovery. In the first place, his thesis on the Physical Phenomena of Harbor Entrances was, in accordance with the rules for application for the Magellanic Premium, sent by him anonymously to the American Philosophical Society. The committee to whose special examination it was submitted consisted of men of the amplest experience in field and office. The society, in a remarkably full meeting, confirmed the justness of their award of the prize medal to Professor Haupt for a discovery beneficial to mankind. Since then, distinguished engineers, George B. Roberts, J. E. Hilgard, Frederick Graff, A. G. Menocal, N. W. Eayres, Joseph M. Wilson, George Y. Wisner, Adolphus Bozano, Joseph J. deKinder, L. E. Gooley, H. C. Ripley, E. A. Gieseler, and the members generally of the American Society of Civil Engineers, have expressed their approval of Professor Haupt's system of the so-called "reaction jetty," in lieu of the present double jetty system. Nevertheless, as things stand, he has been unable to secure thorough trial on its merits before dispassionate judges, or by an unfettered construction, an opportunity for demonstration that it meets and overcomes difficulties heretofore regarded as insurmountable.

At length, however, a tolerably favorable opportunity to prove the

correctness of the system seemed to arise in the treatment of the inlet of Aransas Pass, Texas. To competent maritime engineers the success he there achieved under great difficulties is a perfect demonstration of the correctness of his views. The nearest anticipation found upon record of the correctness of this theory was the sinking of thirteen vessels which were scuttled on the bar off Charleston, S. C., during the Civil War, for the purpose of blocking up the entrance of the harbor.

For the correctness of the statement made as to the truth of this theory, reference is made to the latest map of Aransas Pass, executed by the Coast and Geodetic Survey in February, 1899. The depths thereon shown, when compared with those previously charted, give a good channel to the sea, except for the interruption athwart it of the spur-dike which had been abortively placed there for the deepening of the channel, and which had been reported as having "*disappeared.*" This statement was interpreted by those in charge of the subsequent work as meaning that the dike had undergone submergence in the sand to such a depth as not to interfere with the reproduction of the channel in its original natural position. In point of fact, the work, as designed by Professor Haupt, has more than accomplished what he had set out to do, notwithstanding the obstacle thus unexpectedly thrown in its way, and for which no provision had been made for removal. Let us now learn from the history of the work the difficulties which were overcome, despite the absence of financial support from the general Government, and despite the entanglement of the obstruction placed on the site under preceding administrations, and despite the unusual physical difficulties. The general Government, at the recommendation of the U. S. Engineers, decided, in 1889, to devote the whole appropriation by Congress for the West Gulf Coast improvements to operations looking to the betterment of the Galveston entrance. This afforded an opportunity for Professor Haupt to demonstrate the efficacy of his system at Aransas Pass, Texas, under private control. The Aransas Pass Harbor Company, having secured a franchise from the United States, was induced by Mr. Brewster Cameron, of Arizona, and Col. Geo. W. Fulton, of Rockport, Texas, after their previous attempts to improve the channel by other means had failed, to construct a portion of Professor Haupt's Reaction Breakwater in 1895, with the results already mentioned.

Aransas Pass is an inlet draining Corpus Christi, Aransas and Nueces Bays. The natural depths on the bar there vary from 6 to 8 feet. One of the difficulties to be contended with, arising from the fact that the rise and fall of the tide, which is diurnal, is but 14 inches, and the current generated thereby necessarily weak, is that it becomes imperative to concentrate the largest percentage of the tidal prism for the performance of the function of scouring the channel.

In 1869, the citizens of Rockport had placed a spur-dike of 600 feet in length on the north side of the Pass, thus protecting, in a measure, the channel beyond into the sea, and increasing the depth over its bar by 2 feet. This structure was, however, soon destroyed by storms. In 1870–71 the U. S. Engineers reported that the place was not susceptible of permanent improvement without great expense. In 1879, however, they made an estimate for the work, by which to secure a channel of 12 feet in depth over the bar. The construction for this purpose was to consist of two jetties. The work was begun in 1880, but, unfortunately, by placing a jetty on the west or wrong (because it is the leeward) side of the channel, and additionally in a wrong direction. In 1889, after an expenditure on the work of about $500,000, it was suspended at a time when the depth shown over the bar was only 7·5 feet; decreased from 1887, when it was 8·5 feet. The original plan, with an estimated cost of over $2,052,000, was calculated to secure a probable depth of 20 feet over the bar. In 1885, however, when the work according to the original plan had been extended in the form of a jetty for 5,400 feet, it closed, and in the course of seven years the jetty, which was a spur-dike, was reported by the U. S. Engineers to have "*disappeared*," which was everywhere interpreted to mean that the jetty had become embedded to so great a depth in the quicksands which those engineers had formerly represented as characterizing the bottom, that it was beneath the ordinary level of the bottom of the natural channel, athwart which it had passed on its course.

The Aransas Pass Harbor Company, chartered in 1890 by the State of Texas, obtained an Act of Congress in the same year, by which it was authorized to develop, at its own expense, a channel of 20 feet in depth over the bar. After some preliminary experiments which were unsuccessful, it began work on the Reaction Breakwater in July of 1895, and by the end of October of the same year there resulted 13 feet in depth, secured through the mere initiatory application of this system. It was then discovered, as the consequence of the great scour which had been effected in so short a time, that the remains of the old spur-dike, previously reported as having disappeared, crossed the whole width of the improved channel. This unexpected obstruction, with the failure of the contractor to receive money for work executed elsewhere, resulted in an entire suspension of the work, after he had removed a portion of the old jetty by dynamite. In this extremity the citizens of southwest Texas were impelled to request Congress to appoint a Board of U. S. Engineers to appraise the money value of the work accomplished, with a view of turning the property over to the Government, conditioned upon the immediate completion of the work. The Board appointed under this resolution reported, in the face of the evidence here briefly given, that the work was of no value to the Government. Such a conclusion

may be safely left to the reader's judgment for a verdict in favor of the Reaction Breakwater as tested in the face of the greatest difficulties.

Thus, after a large expenditure by private enterprise, has a work been brought to a close by an accident for which its promoters and director are in no wise responsible. The U. S. Engineers reported immediately after its stoppage, a channel over the bar of only 8·5 feet in depth, but their own accompanying map shows, in the thread of the stream, a depth of 9·25 feet; but this is not all. Stranger still is the fact, not subsequently reported by them, that where, in the map of 1879, just referred to, only 8·5 feet are shown, the late Coast and Geodetic Survey Chart of 1899 reveals over 22 feet in depth. When it is considered that this result has been accomplished there for the first time by a Reaction Breakwater, even in an uncompleted condition, and with a transverse obstruction midway of the current in the channel, it may be well said that Professor Haupt's system for the treatment of such channels has fully vindicated itself in producing such results as those shown in the teeth of the obstacles thus described.

It now only remains, in conclusion, to describe the characteristics of this system, involving the theory upon which it was designed and the mode in which experience shows that it effects its purpose. The fruit of the study of the problem involved, both at home and abroad, and all observations since the first publication of these views, combine to prove the absolute correctness of the conclusion reached in the report.

The Reaction Breakwater is placed immediately to windward of the channel to be protected. It is placed more or less in the natural trend of the channel in the form of a compound and reversed curve. It leaves an open space between the head of the jetty and the land. At its head it flares somewhat away from the channel. This last feature of the construction enables the rising tide to find entrance through the inlet of the bay by means of the opening between the head of the jetty and the land, as well as by the mouth of the channel over the bar. At falling tide the water of the bay, passing through the inlet, follows close to leeward in the jetty, added to by water flowing through the opening of the jetty, which, obedient to the greater momentum of the main stream flowing out of the channel, increases by its volume the effectiveness of scour.

In speaking as follows of the windward and leeward sides of the channel, reference is made only to the annual resultant of the forces along the particular shore under consideration. Placed just to windward of the channel, the breakwater protects it from the material arrested, thus making a protective barrier for the channel, increasing in hardness as time goes on. Back of the landward end of the breakwater, where it flares away from the channel, the form of construction ensures the accumulation of a bank of sand outside of the jetty—the physical resultant of sand accumulation along the line of inertia represented by

the outside of the jetty and the mild inflow of the water between the head of the jetty and the land.

A second parallel, or approximately parallel, breakwater is not requisite to protect the channel, but, as has been said, is objectionable, as entailing less scour than is procurable in the channel, the necessity of constant dredging, and therefore great cost. The direction any channel primarily assumes represents the character of the soil and the resultant of the forces of building and erosion to which it is subjected by nature. It therefore requires for its possible improvement new distribution, on the one hand, of those forces, and on the other hand protection for material on which those forces in their new distribution are exerted. Thus the intervention of man may secure through a new resolution of forces changes in nature better fitted for his purposes. Nature and man, as already intimated, may sometimes join effectively to produce the best possible transmission of energy for given conditions. The conditions will, of course, vary indefinitely in details, but can never involve violation of the principle long since known and utilized.

The claims of Professor Haupt, as originally defined in his paper on the "Physical Phenomena of Harbor Entrances," and as distinctly set forth in his present application for an examination into them by the Committee represented by the undersigned, are fully confirmed by the investigations which this Committee has given to the subject. They may be briefly summarized as follows:

(1) *The form and position* of the breakwater, with reference to the available forces.

(2) *The results* already secured by the partial control of these forces, as shown by existing work at Aransas Pass.

(3) *The economy of time and money* due to the utilization of the energy of the ebb currents, and the protection of the channel from littoral drift.

(4) The construction (formation) by natural agencies of a *counterpart* to the breakwater in the form of a sand-spit or barrier on the lee side of the channel *without cost*.

(5) *The construction and maintenance* of a channel by natural agencies, *without dredging*, in the face of unusual difficulties.

(6) The *lateral displacement* of the material of the bar without sensible *advance seaward*.

(7) In short, the unprecedented economy per foot of depth gained in time, and work accomplished, without expense for maintenance by dredging, marks a distinct advance in maritime engineering.

The literature of this subject of the claims of Professor Haupt to a discovery of the best treatment for certain channels is now somewhat voluminous. We would respectfully recommend its study to our countrymen who are desirous of acceptance of the most advanced

thought on any subject that may be promotive of the economical administration of maritime work, or that may redound to national reputation, or that may even look no further than the doing justice to a single citizen. Especially would we recommend, upon the basis of the record (only a fragmentary portion of which could be here given), to committees of Congress, an appropriation for national public works, and to men generally of national prominence and influence examination of this important subject. It is well known that radical changes in any procedures among men rarely emanate from bodies possessed of the ground by prescriptive right from time immemorial.

For the same cogent reasons which we, the undersigned, have not hesitated to entertain and to present in favor of Professor Haupt's system, as promotive of the best interests of maritime construction on alluvial coasts, we hereby award him, for what we regard as his extremely original invention, the silver medal and diploma of the National Export Exposition, the highest testimonial in our power to grant.

Additionally, we would respectfully refer to the Franklin Institute, requesting that this subject be placed before its Committee on Science and the Arts, with the view to their appointing a jury to consider the expediency of making a further examination of and award to this meritorious invention.

(Signed)

R. MEADE BACHE, Chairman.
AMBROSE E. LEHMAN.
JOHN E. CODMAN.
JOHN HAUG.

THE ELECTRO-CHEMICAL INDUSTRY IN FRANCE.

The following abstract of a paper by J. B. C. Keershaw appears in the *Electrical Review:* Eleven electro-chemical and electro-metallurgical works have 54,000 horse-power derived from waterfalls. The number of electrolytic copper refineries is eight, and it seems improbable that this industry can develop in France, on account of the scarcity of raw copper suitable for refining. There are two plants for the production of aluminum, one with 5,000 horse-power at Le Praz, using the Heroult process, the other with 4,000 horse-power at St. Michel, using the Hall process, but not all of the 4,000 horse-power are used for the production of aluminum. Chlorate is made at St. Michel, under the patents of Gall and Mortlaur, cells without diaphragm being used with platinum electrodes. Chlorate is also made by a similar process at Chedde, where 12,000 tons are available. The calcium carbide industry has developed to a greater extent in France than in any other European country. A modern estimate of the power available in the twenty-six carbide factories places it at 50,000 horse power. The growth of the alkali and chlorine industry has been slow. It is possible that early in 1902 there will be four electrolytic alkali works. Ferro-chrome, ferro-silicon and other similar alloys are produced in electric furnaces at several places. The pro-

duction of ozone by the silent electric discharge through air, and the use of this ozonized air for sterilizing water, for oxidation purposes in the manufacture of perfumes, and for aging wines and spirits, have received much attention in France. In only one case has a practical success been achieved, namely, in connection with the manufacture of heliotropine and vanilia. The Verley ozonizer is used in this plant, near Paris, and 10,000 kegs of the two products named are produced per year. The experiments, made with the Hermite sewage disinfecting process at Havre and Marseilles, about 1890, have not led to any practical success. This process, in which electrolyzed sea-water was used, resembled the Wolff process tried at Havana in 1899, and failure in each case was due to excessive cost.

DAMAGE TO OVERHEAD WIRES BY SLEET STORMS.

The *Electrical World* makes the following editorial comments on this topic:

The damage inflicted upon overhead wires of every description by the sleet storm of the 21st of February exceeded previous records. For several days Philadelphia was telegraphically isolated from the rest of the country as completely as though invested by a besieging army. Baltimore was in nearly as great a predicament, and even New York was crippled in its telegraphic communication with the outside world. Such a condition had not been confronted for half a century. In order to produce such disastrous conditions it is necessary that the air lying close to the surface of the earth should be below 0° C., while the superincumbent strata should be relatively higher in temperature. With precipitation in the form of rain, congelation then occurs upon the incident surfaces, and each wire may become the axis of a cylinder of ice. Telegraph and telephone wires went down for miles. On the Pennsylvania Railroad the poles beside the track were in places carried away, broken, or uptorn by the dozen together, and where the poles stood, the cross-arms were often torn away. Where both poles and cross-arms held their own, the wires were broken in many instances. Electric light wires, being generally larger, suffered less, and trolley wires least of all, save where broken trees and poles fell across the road. The forests were injured for hundreds of square miles. The Atlantic coast was involved in this storm from Maryland to Connecticut.

The question arises whether, in view of the enormous cost of restringing the destroyed lines of wire, it would pay to carry the wires in the open country underground. In large cities the wires are buried already. This is a very large question, involving great outlay and engineering difficulties. It is a question of engineering economics. It would seem, however, that under existing conditions it would not pay to bury the wires at large. While the buried wires would be sheltered from sleet, they would be at the mercy of pick and plow. Wherever a wire runs, through earth, water or air, its continuity is threatened by special dangers, and immunity is a mere matter of degree. Moreover, there would be enormous expense in making and laying the wires and relatively large expense in repairing them, although repairs might be less frequent. The buried wires would be very much slower in transmission than the overhead wires, and the cost of transmission would be increased.

THE FRANKLIN INSTITUTE.

A lecture delivered at Association Hall, February 8, 1902.

The Gases of the Atmosphere.*

By Dr. H. F. Keller,
Member of the Institute.

(*Concluded from vol. cliii, p. 430.*)

The atomic theory of Dalton, which had just been announced to the scientific world, moreover, required that the elements contained in a compound should be in the ratio of either their atomic weights or of simple multiples of these. If this were true of air, then there should have been found 22·2 per cent. of oxygen by weight instead of the 23 per cent. which it contains.

Again it had been observed that when two gases combine with each other, there is either a rise or fall in temperature, and generally a contraction of volume, but no such changes were noticeable when air was artificially made by mixing its constituents in the proper proportions.

It was evident, then, that air is a mixture and not a compound.

Nor is the composition of air absolutely constant. By the aid of more refined analytical methods than had been employed before that time, Bunsen, in 1846, succeeded in detecting slight variations in the percentage of oxygen in samples of air collected in different places and at different times. His figures vary between 20·84 per cent. and 20·96 per cent., and they have been abundantly confirmed by later investigations.

It requires but little reflection to convince us that the composition of air cannot remain constant, and that other gases besides those I have mentioned must be present in it. Consider the many agencies constantly at work to deprive

* In the preparation of this lecture free use has been made of the standard works on the history of chemistry, and especially the writings of Professor Ramsay on this subject.

the atmosphere of its oxygen—the respiration of man and animals, the burning of fuel, the decay of animal and vegetable matter, to mention but a few—and consider, too, the many gases which are generated on this earth of ours, and find their way into its atmosphere. Must we not fear that the air we breathe will in time become so poor in oxygen and so rich in other gases as to threaten our existence?

There is little doubt that even a slight diminution in the proportion of oxygen would seriously affect all living beings, as they are constituted at present, but you need entertain no fears of an impending oxygen famine, or that the human race will some day be snuffed out as our taper was by the accumulation of carbonic acid in the air. The oxygen consumed in various ways is, in a large measure if not entirely, restored to the atmosphere by the green plants which, under the action of the sunlight, assimilate the carbon of carbonic acid and reject the oxygen it contains. But even without this compensating factor, the shrinkage in our supply of oxygen would be almost inappreciable. It has been estimated that, allowing for the oxygen consumed by man and animals at the present rate, and counting that required for combustion as four times this amount, it would be 8,000 centuries before the atmospheric reservoir would be depleted.

To give you some idea of what that means, let us imagine the atmosphere to be contained in a huge vessel, and this vessel hanging from the arm of a gigantic balance; we would have to place upon the scale-pan on the other side 140,000 cubes of copper, each one mile on edge, to counterpoise the air; then, supposing oxygen to be drawn from the vessel at the rate before stated, the total weight would be diminished in a century by not more than four or five of the copper weights.

As to the carbonic acid contained in air, its proportion, too, remains nearly constant — about 3 parts in 10,000. Although this seems very little, the aggregate amount is stupendous; it suffices to supply the entire vegetable world with its carbon.

Huxley has calculated that a section of the atmosphere

resting upon a square mile of the earth's surface contains no less than 13,800 tons of carbonic acid, an amount which is sufficient to furnish the carbon for a small forest of trees weighing 7,400 tons.

In addition to the gases which were discovered in the atmosphere during the pneumatic period, quite a number of other constituents, mostly in very minute quantities, have been detected by the chemists of the nineteenth century.

Among them is a curiously modified form of oxygen, known as ozone. It was first obtained in 1840, by Schoenbein, who showed that it exists in air. It differs from ordinary oxygen chiefly in being far more active, and in possessing the power to destroy noxious gases and germs of disease. Its purifying effect upon the atmosphere, however, has been greatly overrated, for its amount does not exceed one part per million.

Air also contains traces of nitrous and nitric acids, partly combined with ammonia. It is from these nitrogenous compounds that plants derive much of the nitrogen they require for the development of their structure and fruit, the free nitrogen in the atmosphere not being available for that purpose, except in some special cases.

It now remains for me to tell you of the achievements in atmospheric chemistry during the last eight years.

Previous to 1894 it was the general belief among scientific men that the composition of air was certainly one of the subjects upon which their knowledge was most complete. This belief, however, was rudely shaken by the announcement in that year, by Lord Rayleigh and Prof. William Ramsay, that a new gaseous element had been discovered by them in what was supposed to be *pure* nitrogen obtained from air. The great interest awakened by this unexpected find was greatly enhanced when it developed that the stranger, being entirely devoid of chemical affinity, could not be received into any of the old-established families of elements. Owing to this unique character, or rather lack of character, it was given the name of *argon*, the idle one.

Truth is often stranger than fiction, even in science. An account, more fascinating than any of Jules Verne's plausible inventions, might be written of the discovery of argon, under the title perhaps of "The Triumph of the Third Decimal." As I have not the skill of a raconteur, I must be content to recite the principal incidents connected with this discovery.

In one of his great memoirs, entitled "Experiments on Air," Cavendish described the effect of electric sparks upon a measured volume of air, in the presence of caustic alkali, and confined over mercury. You recall the picture of the apparatus I showed on the screen. He noticed that the gas contracted in volume, and, on successively adding small portions of oxygen, while sparks continued to pass, he found that the volume was further diminished, until finally only a small fraction of the gas remained. He ascertained the cause of shrinkage; under the influence of the electric discharges, the nitrogen combined, first with the oxygen of the air, then with the added portions of oxygen, and the resulting oxide of nitrogen was absorbed by the potash, forming potassium nitrate or nitre. The residue, after the excess of oxygen had been removed from it, "certainly was not more than $\frac{1}{120}$ of the bulk of the phlogisticated air (nitrogen) let into the tube, so that if there is any part of the phlogisticated air of our atmosphere which differs from the rest, and cannot be reduced to nitrous acid, we may safely conclude that it is not more than $\frac{1}{120}$ part of the whole." No attempt was made by Cavendish to find out what the residue was, and more than a century elapsed before this problem was solved.

In 1883 Lord Rayleigh, the celebrated physicist, was greatly puzzled by the observation of a difference in the densities of two specimens of what he believed to be pure nitrogen; one of the specimens which had been made from ammonia (a compound of nitrogen and hydrogen) was lighter than the other, which had been obtained from air. The difference was small, but distinct; 201 measures of the "chemical nitrogen" were found to weigh as much as 200 measures of the atmospheric variety, and many careful

repetitions fully established this difference in the third decimals of the densities. The first explanations to suggest themselves were that either one or both preparations of the gas contained some impurity, or that the atmospheric nitrogen might have been somehow partly converted into a denser modification, differing from ordinary nitrogen as ozone differs from ordinary oxygen.

But a most searching investigation failed to reveal the presence of even traces of any other known gas in either one of the nitrogen preparations, nor was it possible to obtain the slightest evidence that the atmospheric gas had been modified in any way.

The attention of chemists had been invited by Lord Rayleigh to the strange anomaly that the same gas had two distinct densities; but no one responded by offering an explanation. Professor Ramsay now asked permission to try some experiments on the nitrogen of the air, and his request was readily granted.

Having observed that *magnesium* slowly absorbs nitrogen, when the gas is passed over red-hot chips of the metal, he proceeded to apply this experience to some nitrogen which he had prepared from air by carefully removing all the oxygen, moisture, carbon dioxide, etc. As the volume of the gas diminished—the absorption being exceedingly slow—the density was found to increase. This encouraged Ramsay to repeat the experiment on a larger scale, and, by the aid of an elaborate apparatus in which the gas was made to circulate for many days over the heated metal, he succeeded in absorbing all but a very small residue, which proved to be nearly half again as heavy as nitrogen. To make sure of the complete removal of the latter gas, he mixed the residue with oxygen, and, taking advantage of Cavendish's experience, exposed the mixture to a rain of electric sparks in the presence of caustic soda. Further contraction ensued, and, when the excess of oxygen was finally removed, a gas having a density twenty times as great as that of hydrogen, and one and one-half times that of nitrogen, remained.

The next step was to ascertain whether this gas contained any of the known elements, and the best way (the only way,

in fact) to do this was to make a spectroscopic examination of it.

The spectroscope, as has been explained in a previous lecture of this course, is an instrument consisting of prisms and lenses so arranged as to separate the various kinds of light into their components and permit the examination of these components. Under proper conditions every element emits a light which is peculiar to it. Thus, when gases in a rarified condition are subjected to the discharges of an induction coil, they glow and send out rays of different colors, which, viewed through the spectroscope, betray the chemical nature of the gases. To this end, the specimens to be examined are enclosed in glass tubes provided with platinum wires at both ends and contracted in the middle to a fine capillary—Pluecker's tubes, as they are called after their inventor. On connecting the wires with the terminals of a coil, the electric discharge passes through the gas, and the glow appears most brightly in the capillary part of the tube.

Here, for instance, is a Pluecker-tube containing hydrogen, which gas we instantly recognize by three characteristic lines in its spectrum: one red, one blue, and one violet.

Ramsay's new gas still contained nitrogen, for it showed the numerous bands which characterize this element; but it gave in addition many other lines, mostly red and green, which could not be identified with those of any known element.

While these experiments were in progress, Lord Rayleigh was engaged in repeating Cavendish's experiment of sparking atmospheric nitrogen mixed with oxygen in the presence of caustic alkali. His results confirmed Cavendish's statement that a small, unabsorbable residue finally remains, and also proved that this residue is proportional to the volume of the nitrogen experimented upon. He, too, noticed the peculiar spectrum of the new gas.

The two discoverers now agreed to go into partnership to complete the investigation, and to make a preliminary announcement of their discovery of a new element in the atmosphere.

By means of improved apparatus they were able to isolate argon from air in considerable quantities, and to obtain it free from nitrogen. Its exact density was determined at 19·94, and its spectrum was carefully studied and mapped. The other physical properties, too, were very fully determined, but nothing remarkable was noticed about them, except the rate of speed at which sound travels in this gas. The velocity of sound in a gas is influenced by the greater or less complexity of the smallest particles or molecules of that gas, and the velocity of sound in argon proves that its molecules, unlike those of the more common gaseous elements, which consist of two atoms, are single atoms. In other words, the molecule and atom of this element are identical.

But it is from a chemical point of view that argon presents the greatest interest. It differs from all the elements previously discovered in that it is absolutely devoid of chemical activity; no means at the command of modern science has been left untried to coax it to combine with other elements, but it has steadfastly maintained its freedom. Neither prolonged exposure to the most powerful electric discharges, nor contact with the most chemically active substances, such as fluorine gas, evoked the slightest response of a chemical nature.

Science is knowledge reduced to system. The more advanced our knowledge grows, the more comprehensive, as a rule, will be the system. Not only does such a system then permit an orderly arrangement of the known facts, but it will also provide, to a great extent, for the fitting in of new discoveries; indeed, these can often be foretold from gaps in the system. The progress of chemistry during the nineteenth century has made it possible to formulate a comprehensive scheme, known as the periodic system, in which all the known elements have found a place, and in which the existence of certain gaps has led to the prediction and subsequent discovery of other elements. Gallium and germanium, for instance, were discovered years after their existence had been predicted, and they have been found in every important detail to answer to the elaborate

descriptions which Mendeljeff, the author of the periodic system, had given of them.

But the discovery of argon had not been thus prognosticated. After its physical and chemical character was ascertained, Ramsay was very anxious to find its place among the other elements. Inasmuch, however, as it shows no resemblance to any of the members of the groups which constitute the system, there was no gap in these groups into which it would fit, and it seemed for a while as if a serious defect in Mendeljeff's system had been uncovered.

This difficulty served as an incentive to Ramsay to continue his investigation, and thus led him to the discovery of the "companions of argon," four inert gases resembling argon and, like it, constituents of air.

Although all efforts to produce compounds of argon had been in vain, Ramsay believed it possible that such compounds might exist in nature, and he instituted a diligent search for sources of the gas, other than the atmosphere. He found that it is contained in most natural waters, dissolved with the other atmospheric gases. His attention was further directed to a remarkable observation which had been made in the laboratory of our Geological Survey, in Washington, by Dr. Hillebrand. On treating the rare uranium mineral, *cleveite*, with sulphuric acid, this chemist had obtained a colorless gas, which he believed to be nitrogen. Ramsay procured considerable quantities of the mineral, and extracted the gas in the hope of detecting argon in it. After removing nitrogen in the manner already described, he made a spectroscopic examination of the remaining gas. To his great surprise, the lines he observed, though very brilliant, were not those he expected to see, but those of an element for which chemists had vainly been searching this earth for many years. It was during the eclipse of 1868 that a French astronomer, Janssen, had noticed these lines in the spectrum of the sun's chromosphere, and they had been attributed by Frankland and Lockyer to the presence of an unknown element, to which the name helium had been given, from helios, the sun.

The existence of the supposed solar constituent was thus

proved, and no time was lost by Ramsay in acquainting himself with the character of the welcome visitor, who had so narrowly escaped making his terrestrial debut on this side of the Atlantic. It turned out that helium bears the closest resemblance to argon. Like the latter, it is an inert, colorless gas, and its molecules, too, are single atoms. But it differs from argon, not only in its spectrum, but in density; it is only one-tenth as heavy, and, next to hydrogen, the lightest substance known. Of all gases it is the most perfect, and the only one which has not as yet been reduced to the liquid state.

The pronounced resemblance in their properties, together with the relation observed between their atomic weights, made Ramsay suspect that helium and argon are members of a more numerous family of elements. In an address he delivered in 1897 on "An Undiscovered Gas," he ventured this remarkable prophecy: "There should, therefore, be an undiscovered element between helium and argon, with an atomic weight sixteen units higher than that of helium and twenty units lower than that of argon, namely, twenty. And, if this unknown element, like helium and argon, should prove to consist of monatomic molecules, then its density should be half its atomic weight, ten. And, pushing the analogy still further, it is to be expected that this element should be as indifferent to union with other elements as the two allied elements."

A systematic search for this hypothetical element was at once begun, and, after many unsuccessful experiments, the missing link was found, the prediction being fulfilled in every particular.

A new invention furnished the means to this end. I have mentioned that gases can be converted into liquids; it is done by either cooling or compressing them. In some cases liquefaction takes place easily, that is by lowering the temperature only a little or by moderately increasing the pressure, while in other cases the gas must be exposed to very intense cold, and a great pressure applied at the same time. The liquefaction of air, for instance, can only be accomplished by reducing its temperature to, say, 300

degrees below zero, and applying a pressure of about 500 pounds to the square inch. Until 1895 such conditions could be brought about only at great expense, and the liquefaction of air and other difficultly liquefiable gases had been conducted on a small scale by a few skilful experimenters. In that year, however, a process was invented by which air can be liquefied at small expense and in considerable quantities.

Of two machines designed for this purpose, the one constructed by Dr. Hampson was used by Ramsay and his assistant, Dr. Travers, to prepare large amounts of liquid air, for the double purpose of using it as refrigerant in liquefying argon and to see whether the liquid argon or the liquid air itself would not yield up some of the undiscovered element.

The results surpassed all expectations; on distilling the liquid obtained from about 4 gallons of argon gas, it was found that a gas lighter than argon passed off with the first portion distilled; and, on slowly boiling away the liquid air, gases heavier than argon were obtained from the last portions.

The spectroscope was again called to aid, and no difficulty was experienced in recognizing three distinct new elements. The light gas from the argon emitted a brilliant red light when sparked in the Pluecker tube, and received the name *neon* (the new one), and of the two heavier ones obtained from liquid air one was called *krypton* (the hidden one), and the other, *xenon* (the stranger), the former being characterized by a yellow and a green line in its spectrum, the latter by a very complex spectrum in which blue lines are most conspicuous.

Time does not permit my dwelling longer upon the progress of this wonderful research; suffice it to say that Ramsay and Travers have succeeded in separating the companions of argon from air and from each other, in determining their principal properties, and in estimating approximately their proportions in the atmosphere.

The very close resemblance which the five new elements bear to one another, and the very regular manner in which

their physical properties vary, make it certain that they constitute a natural family, which, as Professor Ramsay has lately pointed out, fits perfectly into the periodic system, forming a connecting link between the elements of extreme positive and negative activity.

Their relative amounts in air are estimated to be:

·937 parts of argon per hundred.

One or two parts of neon per hundred thousand.

One or two parts of helium per million.

About one part of krypton per million.

About one part of xenon in twenty million.

You would doubtless like to know the function of these inert gases in the atmosphere, their *raison d'etre* in nature. I regret to say that, so far as we can see at the present time, they serve no useful purpose. Oxygen is the life-sustaining principle that keeps everything going on the earth; nitrogen restrains the activity of oxygen within proper bounds; carbon dioxide, ammonia, nitric and nitrous acid are necessary for the growth of plants; vapor of water plays a main part in those important and never-ceasing changes which we call the weather, and even ozone contributes its share of usefulness in freeing the atmosphere from deleterious matters, but no apparent benefit to the living world can be instanced as a result of the presence of argon and its companions in air.

While this seems an unsatisfactory admission with which to conclude our story, let us bear in mind that, after all, we know but little of the secrets of nature, and that future investigations will continue to alter and enlarge our views.

THE TUNNEL BETWEEN SCOTLAND AND IRELAND.

The proposed railway tunnel between Scotland and Ireland, judged as one element of the general scheme or schemes which are now being mooted for shortening the distance of the ocean passage between Europe and America, is placed in somewhat the same category as the late Austin Corbin's dream for the creation of a great terminal port at Montauk, at the eastern end of Long Island; there being this difference, however, that when judged on that ultimate basis to which all such schemes must come—financial practicability—the Scotland-and-Ireland tunnel is even less feasible than Corbin's project. The cost of the tunnel is estimated by the co tractors at $50,000,000, exclusive of

interest, and, as matters now stand, there is not nearly sufficient traffic, either freight or passenger, to enable the scheme, if completed, to earn interest on the cost of construction. Nevertheless, in view of the rapid growth of commerce and the vast accumulation of capital seeking investment, it is conceivable that conditions may arrive in some future day that will guarantee the construction of a thirty-four and one-half mile tunnel such as this.

The engineering features of the tunnel were discussed recently in a paper read by James Barton, M.I.C.E., before the International Engineering Congress at Glasgow. Of the three possible locations for the tunnel, the one selected lies between Wigtonshire, Scotland, and the Irish coast, at a point where the distance from shore to shore is within twenty-three miles. The maximum depth of water varies, according to the line selected, between 480 and 900 feet. The route forms a through line between Carlisle and Belfast, and has the advantage of providing the best route from Scotland to the whole of Ireland, and from the north of England to Ireland. The survey for the tunnel proper commences five miles from Stranraer railway station and finishes five and a half miles inside the shore line of the Irish coast, the total length of the tunnel being thirty-four and a half miles. Leaving the tunnel, the line extends for ten and a half miles to the city of Belfast. The total length from Stranraer to Belfast is fifty-one and a half miles, thirty four and a half of which is tunnel, and twenty-five of it beneath the sea. The roof of the tunnel is 150 feet below the sea bottom. The proposed heading is 7 feet high by 10 feet wide. It is expected that the portion of it which is driven through the Silurian will be cut as rapidly as the Simplon tunnel, while progress through the Keuper marls is expected to be more rapid. It is estimated that the whole of the heading would be completed in less than ten years, and the tunnel finished in about twelve years. This estimate is based upon a comparison of the speed of driving four notable tunnels. The Mont Cenis was driven at the rate of 6 yards a day, and at a cost of $1,120 per yard. In the St. Gothard the maximum speed was 10 yards a day, at a cost of $710 per yard. In the Arlberg the maximum speed rose to 12 yards a day, while the cost was reduced to $535 per yard; and it is expected that on the Irish tunnel, judging from the quality of the material to be passed through and the improved methods now being used on the great Simplon tunnel, the speed will be increased and the cost per yard reduced still further. As to the question of water entering the tunnel, although the uncertainty on this point is admitted, the author of the paper does not consider that the difficulty will be a serious one. No water leakage in any great quantity occurred during the construction of the Severn or the Mersey tunnel, at least in those portions of these tunnels that were immediately beneath the sea; and it is believed that the sea bed below the Irish tunnel has probably closed all faults in the rock sufficiently to keep out sea-water in any but easily-handled quantities. The line will be operated electrically from power stations located near the main shafts at each end of the tunnel; and it is proposed to run trains at a speed of sixty to seventy miles, thereby reducing the time in the tunnel to about half an hour.—*Scientific American.*

THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, February 19, 1902.

President JOHN BIRKINBINE in the chair.

The Metric System of Weights and Measures.

(*Continued from vol. cliii, p. 418.*)

CORRESPONDENCE.

[The following letters have been received by the Secretary and by the Committee as contributions to the discussion of the report. In some instances these have been edited by the omission of irrelevant matter.—THE SECRETARY.]

WILLIAM SELLERS & CO., INCORPORATED.

PHILADELPHIA, March 20, 1902.

To the Secretary.

DEAR SIR:—The report of the special committee of the Franklin Institute is probably based upon the answers received to the "questions discussed at the meeting of sub-committee, January 17, 1902."

These questions appear to me to be very inadequate for the gravity of the subject under consideration. The concluding resolution of the special committee invites the National Government to force the metric system upon all of its departments as rapidly as may be consistent with the public service. This may mean something or nothing, as it can scarcely be for the public service to adopt a system of weights and measures in advance of the ability of the country to supply the raw material it requires in accordance with the new system.

The disadvantage of the French metric system is, that it is an attempt to measure time, space and matter decimally, whereas the decimal system is only specially adapted for computing numbers.

Believing, as I do, that for this country to adopt the French metric system would be an error of the gravest character, I submit herewith a series of questions that each reader may consider and answer for himself, so as thereby to arrive at an opinion concerning weights and measures based upon considerations other than that of uniformity with the foreign countries which have adopted the French system.

(1) Assuming the desirability of an international standard of weights and measures, is it so desirable that we should abandon for it all of our

engineering literature, all of our small tools, standard gauges and screw-threads now based upon our standard inch, all of our rolling-mill rolls, with all other special machinery for the preparation of raw material for the mechanical engineer, all of our binary divisions in common use and our binary division of our decimal monetary system?

(2) Assuming the advantages of the metric system for purposes of computation, and as the length of the French meter is not a necessary part of the system, would it not be desirable to adopt a metric system for this country with a length for the meter of 40 inches, whereby 25 mm. would exactly equal 1 inch, with measures of weight and capacity based on this meter as in the French system, so that the system could be used decimally or by whole numbers and fractions as in our monetary system?

(3) As such a system need make no change in our measures of length or in our fractional divisions of length and measures, and would afford the advantages for computation claimed for the existing metric system, would such advantages compensate for the small divergence from the French system?

(4) If they would not, then we are asked to abandon all that we have of weights and measures and our engineering literature based thereon, to adopt a foreign system for the sake of uniformity alone. Would any possible gain compensate us for the cost and confusion of such a change?

(5) Would any advantages claimed for the metric system compensate us for abandoning the standard inch and our fractional and decimal divisions of it, with our engineering literature based thereon?

(6) Would the advantage of a system which could be used decimally and duodecimally, if adopted by us, induce foreign countries to ultimately adopt our system?

(7) The use of the metrical system is now permitted in the United States; if it is so much better than our own, should it not gradually displace our system?

(8) If our export business should largely increase to metrical countries, with whose measures such exports might have to conform, would not this introduce the metrical system into our country without friction and without special legislation?

(9) Should the National Government pass any bill to enforce the use of the French metrical system in any of the departments of government?

Yours truly,

WM. SELLERS.

To the Secretary of the Franklin Institute:

The subject seems to me hardly to require or to permit any extended discussion. It has been familiar to the world, as a question of import-

ance in economics and the industries, in science and in art, for a century, and the system has become general all over Europe and throughout the world, except in the United States, Great Britain and their colonies; in some cases it is used in these countries, and in others generally in their dependencies. The advantages and relative disadvantages of its adoption are perfectly well understood and have been illustrated by every nation which has accepted it. No nation now enjoying its advantages could be induced to exchange it for our heterogeneous "system" of weights and measures—our no-system; rather—and the testimony in its favor from those who have had experience and are best entitled to give trustworthy evidence is practically unanimous. The only voices against either the system itself or its adoption are usually raised where that experience has not been had. It is making progress, slow to be sure, but none the less steady, in our own country and in Great Britain. The question is not, after all, on its adoption, but rather regarding the time and the rate of advance toward its installment as a national and officially accepted system.

A "free country," such as ours, perhaps mistakenly, is supposed to be, is at some disadvantage beside the autocratic or monarchical and the bureaucratic country in its inability to force upon individual citizens even the most desirable of improvements, and we must probably assume that the progress of this great movement cannot be greatly forced and that it must advance as people can be brought to see its usefulness in the individual case. It can probably only be accelerated by suasion, not by force. It must be by missionary work rather than by legal enactment. The statute must probably follow general voluntary use of the system.

In our country the mob may sometimes dominate the public in the city and lynch-law may prevail in the darkest country districts; but deliberate compulsion of the people through the law is not likely to be successful, even in so good a cause. A man may not be free to work where he chooses and when he chooses and for what pay he chooses, to make his own bargain or to select his own vocation in a so-called "free country;" but he will insist that he shall at least be permitted to weigh and measure in feet, inches and barleycorns, in bushels, pecks and various sorts of gallon, and in ounces, pounds and tons of 2,240 or of 2,000 pounds, as he may see fit, rather than adopt a decimal system that will save him time, trouble and nerve-strain and prolong the life of his children, or which will, in business, decrease cost and increase profit and promote accuracy and interchangeability and in the world's intercourse facilitate all commercial and financial transactions.

The resolutions presented for our consideration by our committee are most reasonable and conservative, and will not, I imagine, provoke much opposition. That last saving clause will reconcile all views and unite all parties. I do not see, however, how they could make their

action more radical under the circumstances. The system must probably make its way on its own merits, and I suspect that any attempt to force its introduction at a higher rate of speed would simply awaken otherwise dormant opposition and retard the movement seriously. An exasperated opponent will be active, energetic, persistent and industrious; a mildly favorable protagonist will be worth less in the contest than the utterly indifferent. The interested opposer of any statute proposed will count for more than will a dozen of the other sort on the other side.

There would seem to be no reason, however, why the National Government and its departments should not take advantage of the present situation, and availing themselves of their legal option, push the adoption each year sensibly further and into new divisions of their work. The equivalent measures in the older system should be retained and probably must be for a generation still to come; but the metric system should be the standard, not the British. The departments, in making their computations, could and should usually employ the metric system, and at the close of the work express the final result in metric quantities with the equivalent British no-system value placed after it in parentheses. Where the details of computations are given, they should be given in metric, rather than British terms and figures.

In scientific work, it is desirable that, as in fact is now usual, all work should be performed and all results given in the metric measure and no equivalents need be stated. In the applied sciences, where the man of science and the man of business are alike interested and are necessarily in communication, the equivalents should always be given until, in some perhaps distant period, the latter as well as the former has come to think as well as work with the simpler and more economical system and is at least as familiar with it as with our cruder muddle of measures of to-day.

In the points of contact of the governmental and of the scientific departments with the business world, it would be perfectly easy, if they chose, for the officials responsible for contracts to call for bids in most cases with metric measures given in the specifications, and, where it might be obviously practicable, to have their requirements stated in metric measures on every drawing and every specification. While it would be impracticable to-day to secure such a change in the purchase or construction of many standard machines and interchangeable parts, there are already many things which may be obtained on a metric specification and the number is constantly increasing. This custom on the part of Government and its departments and of scientific men and their departments would do much to facilitate the advance proposed. Much discretion would be necessary in this matter; but I think it would be entirely practicable.

Once the system becomes sufficiently generally known and its merits revealed by moderate extension of its use, the people of the United States may be relied upon to adopt it very quickly. The difficulties are mainly those which meet us in our attempts to secure any other sort of action by the people or their representatives. It comes of the primary difficulty of securing their attention and obtaining an opportunity to demonstrate the facts. The rapid introduction of the Australian system of ballot, once the people and their legislators had been brought to seriously consider it, the now rapid progress of the voting machine, the introduction of technical education and scientific professional training, the progress of forestry and a hundred other movements illustrate the point which I make here. The flow of the current of progress with us is like that of a stream through the gravel of the plains. It cannot be forced to a rapid permeation; but gravitation is always working and never is there an instant's cessation; it is only a question of time when the stream will find its way through to a clear course. There is a powerful gravitation working as constantly to urge the advance of this, as of every other, recognized improvement and we may be sure that if we simply clear away obstacles as we have the opportunity and open the channel here and there as we may, gravitation will surely, and in time rapidly, distribute the flow to all parts of the land and into every division of our industries.

It must not be forgotten, however, that our manufacturing industries have to-day become enormously extensive and that they constitute the fundamental element of our industrial system; even the art of agriculture having now become largely dependent upon mechanism and almost, perhaps quite, deserving of being denominated a branch of mechanical engineering. Our wealth in machinery and mechanism has come to be almost inconceivably great, and every piece of every however complicated mechanism is an expression, and a perpetuating memorial, of the cumbersome and costly miscellany which we have been accustomed to call a "system," the British "system" of weights and measures. Every minutest part of all this immense accumulation of machinery is an obstacle in the path of reform; every dollar of capital invested in the construction and in the employment of this apparatus, and the vastly more still to be built on that unsystematic "system," will be more or less an obstacle to change. Time and patience and steady persistence, without unreasonable aggressiveness, and reinforced by the natural tendency through moral and social gravitation towards improvement, efficiency and economy, will gradually remove all serious obstacles and, thenceforward, the advance will be rapid and smooth and fruitful of good. The English-speaking nations will not always lag behind in this, any more than in any other, direction of progress. They have usually

set the pace and may be fairly relied upon to maintain their standing hereafter.

Our work to-day is that of opening the way, of smoothing the road, of removing all meaningless obstacles and of teaching the captains and the pilots of industry their opportunities and their inducements to follow the paths thus made clear for them. Above all, we are to help make the metric system familiar to every child and youth in the land, and so familiar that it shall serve their purposes every hour in the day and better than the older and cruder "system" and its barbarous nomenclature. This being done, we may confidently leave the rest to time and the coming generation.

R. H. THURSTON.

SIBLEY COLLEGE, CORNELL UNIVERSITY,
February 17, 1902.

To the Secretary:

In accordance with request contained in yours of February 15th, I take this opportunity to make a few comments upon the subject to be considered before the meeting to be held this evening at Franklin Institute, namely, the adoption of the French metric system, primarily in the workshops connected with the different departments of the Government.

My views in regard to the matter have been abundantly expressed in the report of the majority committee to the Franklin Institute in 1876, also in my paper in regard to the Metric System in the Workshops, read before the Society of Mechanical Engineers, November 4, 1880, and other papers, and I see no reason to change my views as therein expressed. I have always been a strong advocate of the legalization of the metric system conjointly with our own. I have also persistently advocated the standardization of commercial material in harmony with the shop sizes in common use, all of which depend upon the inch as a unit.

The first question asked by the sub-committee of the Franklin Institute in their paper dated January 17, 1902, assumes the desirability of an international standard, namely, "Can we expect nations using the metric system to abandon that and adopt our system?" and I note that this is replied to in the negative.

In this connection I desire to call the attention of the members of the Institute to an interview I had in 1884 in England with Sir Joseph Whitworth, who, as you are aware, was noted for his improvements in the design of machine tools and the preparation of standard gauges, etc. (He at that time was in feeble health, and in point of fact was called from this life a short time afterward.) He raised this very question of the futility of asking foreign nations to adopt the standard of England

even with improvements as to the simplification of the units of measurement and weight, but he urged that I should use my influence to have the United States in the first place adopt the meter of *40 inches* in place of that now represented by a rod of platinum in the archives at Paris, measuring 39·371, approximately. This change would add only ⅝ of an inch to the length of the French meter, and this would appear less in its subdivision, but it would result in an exact correlation between the English unit and its multiple and the metric system. As the comparison now exists, we have the anomaly of assuming 25·3995 millimeters to be equal to 1 inch, while if the change suggested by Whitworth were made, our unit would be 25 millimeters exactly ; 100 millimeters (1 decimeter) would be 4 inches exactly ; 300 millimeters would equal 1 foot, and 900 millimeters would be 1 yard. The difference of weight that would result from the cubing of these dimensions, or any portion of them, and their contents in the weight of distilled water at a certain temperature, would be insignificant. Already by Act of Congress it has been determined that for postoffice uses, 15 grams French weight shall be taken as equivalent to ½ ounce, although the weight of 15 grams is slightly more than the weight of the ½ ounce of the postoffice measurement.

Should the United States adopt a meter of 40 inches, all the standard dimensions of material used in the mechanic arts, as I have said, would be commensurate with our inch unit, and in harmony with our present metrological system.

I present this matter for the earnest consideration of the members of the Franklin Institute, for the reason that, while it is not reasonable to expect the French people and others to give up a so-called logical system of metrology, if the United States should adopt a metrical system with a 40-inch meter as the primary unit, the Empire of Great Britain, now representing three-fifths of our commercial interests, might adopt the same, and it seems reasonable to suppose that other nations would find it to their interest and advantage to fall into line.

In the second question of the circular referred to, the French metric system is claimed as advantageous in computation, owing to its harmony between weights and lineal measurements, which it is claimed can be borne in mind without effort. It would be interesting to know how many of the members who signed this report can repeat off-hand the system in all its details without error. I have closely observed the use of the French metric system both here and abroad, and note that the knowledge of each user covers only what relates to his own particular business and goes no further. A tailor in France or Germany or any other country where the French metric system is legalized has a tape-measure divided into centimeters and half centimeters, precisely as a tailor in America has a tape-measure divided into inches, halves and quarters. The finest measurement they have occasion to use is respectively ¼

of an inch in America, and 5 millimeters or approximately $\frac{1}{5}$ of an inch in France or Germany.

The division of material bought and sold by weight into halves and quarters is natural to the human mind. Its division into fifths or tenths is not conceivable. What is possible in money is not practicable in the market. Half of the kilogram, nearly equivalent to the pound, had to be legalized in France and Germany, and this again is subdivided into quarters and not into ten parts in such materials as meat and butter.

As to memorizing such a system, it is, I fear, more easily forgotten than acquired, as has been proved time and again by questioning those who are compelled to use it. The difficulty with English-speaking nations is that there is no correlation between the metric units and the inch, foot, yard or pound, but if we make the meter 40 inches long this difficulty disappears at once.

Without attempting to go further into the discussion of this subject, I would say that if the Institute desires to make any recommendations looking toward a change in our standards of measurement, I deem it advisable to call the attention of its members to Sir Joseph Whitworth's suggestion, which in my judgment is the simplest and wisest solution of the problem that has been presented.

I remain, yours truly,

COLEMAN SELLERS.

PHILADELPHIA, February 19, 1902.

To the Secretary of the Franklin Institute:

The commotion caused by the disturbance of established customs has been compared by Dr. Holmes with that which follows the overturning of a large flat stone which has long lain in the field. The good Doctor well describes the panic of its conservative population upon being deluged with the unaccustomed sunshine.

In the days of our forefathers such a disturbance accompanied the attempt to substitute the dollar and the cent for the pound sterling and its cumbrous subdivisions.

In our own days it took a mighty effort to convince our manufacturers that the blue-print was worthy of their attention; and now the effort to substitute the meter and the centimeter for the yard, the foot and the inch, the cubic meter and centimeter for the cubic yard, foot and inch, and the various gallons, quarts, pints, bushels, pecks and what-not, and the kilogram and gram for the numerous tons, hundredweights, quarters, pounds, ounces, pennyweights, scruples and drachms, is giving rise to discussions like the present one—discussions upon which our posterity will assuredly look back with compassionate wonder.

That either of these reforms, instead of being immediately hailed

with delight and accepted in all its fullness, should have had to fight its way upward through dense overlying strata of stolid opposition, is a fine illustration of human conservatism, which includes an adherence to the existing order, in any given case, not for its merits, but simply because it is old; an adherence due to that mental inertia which makes us rather bear those ills we have than go to the trouble of thinking about anything in particular, and which yet, paradoxically, induces its votaries to take infinite pains and exhibit remarkable ingenuity in showing why any particular improvement should not be adopted.

But even that peculiarly aggravated phase of conservatism which prefers the British to the American coinage and the British to the civilized metrology, weakens before the all-subduing influence of time; and now, more than a third of a century since the use of the metric system was made lawful throughout the United States, the opposition to it is perceptibly weakening.

Even the manufacturer, who has so long been insisting that the introduction of the metric system meant his ruin, now admits that, when a large foreign order depends upon doing work in the metric system, that system is found not to be an insuperable barrier after all, and the order is taken.

To argue the superiority of the metric over what we may well blush to admit is still the British and the American system, would be a reflection upon the intelligence of the members of the Institute. In the language of the Editor of London *Engineering*, "the time has gone past when it was necessary to furnish arguments as to the advantages of the metric system over our own confused methods."

To my mind, the only serious reason for hesitation in pushing the adoption of the metric system, is that which, at first sight, appears to be its chief merit, viz. : its decimal basis.

The number 10 came to us as a basis of notation through our having each 10 fingers (including thumbs). Its unfitness for the purpose becomes manifest whenever we have occasion to think of the half of a quarter dollar and realize that this half is 12½ cents, bringing us at once into inconvenient fractions. As my good friend, Mr. Benjamin Smith Lyman, says, in his paper entitled "Against Adopting the Metric System:" "If our early predecessors, in learning to reckon, had but omitted to count their thumbs, * * * they would have saved the world a vast deal of labor, and would almost have abolished the use of vulgar fractions."

Undoubtedly, some future generation will find itself using 8 or 12 or 16, instead of 10, as a base, just as our generation finds itself using the Arabic instead of the ancient Roman numerals. Therefore we must regard the metric system, not as a finality, but simply as a temporary expedient for the public welfare.

At first sight it might appear that the general use of the metric system, with its decimal base, would tend to perpetuate the decimal system, and to render more difficult the inevitable transition from it to the vastly preferable octonal or duodecimal system. If so, we might properly question the propriety of sacrificing the future for the present gain by adopting the metric system.

But, in the first place, the abandonment of the decimal base is so radical a step that we can hardly hope for its accomplishment during this or the next generation, and those generations might as well be delivered from the manifold inconveniences of the present alleged system.

In the second place, it seems altogether reasonable to hope that the metric system, by educating the popular mind up to the advantage of simplicity in matters of arithmetic, may rather help than hinder the ultimate substitution of a new basis of notation.

But, granted that there is no question as to the desirability of the speedy general adoption of the metric system, we may still ask whether the Franklin Institute, by taking the action now proposed, will help or hinder that consummation.

Certain experience of my own, in the use of argument based upon fact, as a means of bringing about the adoption of another sort of meter, has led me to question the efficiency of that method of obtaining popular approval of a measure smacking of innovation; and I have been ready to say, in my haste, that the speediest way to bring about the reform of an abuse is to keep quiet and let the abuse make itself intolerable. Until it does so, until the public really wakes up to the nuisance, argument against it only wearies those who do not keenly feel its burdens, and awakens the resentment of those who have some interest, if only the interest of conservatism, in maintaining it.

In all such movements, however, there comes a time when an organization like the Franklin Institute, universally respected as an authority (though coolly left without the support necessary for a decent existence), is looked to for its voice in the matter, and should feel that it owes it to the unappreciative public to utter that voice in no uncertain tones; and later there comes a time when the community, at last aroused, asks of the authority, "What! Slumbering still?"

It is now a quarter of a century since the Franklin Institute, by the narrow majority of 41 to 39, adopted a report opposing a proposition looking to the extended use of the metric system. At that time the Institute might have endorsed the metric system for *the system's* sake; but the time has now come when she *had better* endorse it for *her own* sake. She cannot afford to neglect the present opportunity of reversing her action of 1876.

JOHN C. TRAUTWINE, JR.

PHILADELPHIA, February 19, 1902.

To the Secretary of the Franklin Institute.

SIR :—I beg to offer as a contribution to the discussion of the metric system the following abstract of an argument of mine on the same subject before the Engineers' Club of Philadelphia, in 1895, together with a few additional remarks :

ABSTRACT OF ARGUMENT BEFORE THE ENGINEERS' CLUB IN 1895.—The arguments urged for the metric system are its convenience, either in use or in computation, and its ideal beauty.

The meter has no particular convenience in use, and is not especially fit to be a base of geographical measures or terrestrial arcs, since it is not even a simple subdivision of a meridian; and, though it were, the decimal subdivision of circles has never yet been found generally convenient. The length is passably good for cloth measuring, but for other use is either too long or too short a unit. To carpenters and smiths always in all countries the foot has been found the convenient unit; to sailors and miners, the fathom; and to machinists, the inch. The foot or two-foot rule readily folds into convenient subdivisions; the meter does not. Coleman Sellers, a highly competent authority of great experience, both with the metric and the common system, has shown that the inch is a far more convenient unit for machinists than any metric measure is; and that a change from the inch would cost them millions of dollars.

Convenience in computation is claimed for the metric system on account of correspondence with the ordinary decimal arithmetic. But the inconvenience of our common system is much exaggerated, and, in fact, causes difficulty only to the smallest children. The metric system, owing to the greater number of digits required, often makes the multiplication of dimensions together harder than with our measure. With our decimal money, in use for more than a century, mercantile men find it convenient to use halves, quarters, eighths and sixteenths, as every market report shows. Professional men that need frequent computations sometimes divide their unit decimally, as the surveyor his foot or chain, the machinist his inch, the chemist his weights, but the number of such men is probably not one in a thousand of the whole population. The number of men in commerce that would profit by increased ease of such computations is also comparatively small. Besides, our commerce with British countries is much more than with all others put together, and always will be, because one-third of the human race and one-fourth of the land of the world are under British and United States rule. Some countries have found profit in adopting the metric system because they had previously many different provincial systems, and uniformity is clearly a gain; but any uniform system would give that benefit. A radical change of system would require for many years frequent recomputation of old measures, both those of deeds and those of the Government

surveys, and in town-surveying for building purposes. In manufactures, too, many new patterns, tools and other appliances would have to be made, with great disarrangement of the present complicated, widespread system of interchangeable parts, shop sizes and merchant sizes, at a cost of many millions of dollars.

As for ideal beauty, the meter is merely a certain French bar of metal, not really a simple subdivision of any meridian; and any meridian that might be selected would be a local, national, political standard. The only beauty of the metric system, then, is its agreement with the common decimal arithmetical notation, a notation that is itself far from ideally beautiful, and that may some day be replaced by a better one. An eightfold notation would agree with the natural, most convenient method of subdivision by successive halving, and would almost entirely do away with vulgar fractions, and might be made easy of adoption by reforming our numeration with a dozen new words so simple that they could be learned in two minutes. Our present measures—the foot, hogshead, bushel, gallon, pint, pound, and many others—would harmonize admirably with such an eightfold notation, and with slight changes could be made to correspond exactly, if it should be thought desirable. The foot itself might be derived from twenty-seven times successively halving the earth's equator, the only standard the earth can give that is not local, and that can have a simple relation to simple subdivisions of the earth's surface. Such a foot would be only $\frac{1}{18}$ of an inch shorter than the average of the thirty-two principal European ante-metric feet, and less than $\frac{1}{4}$ of an inch shorter than our American and English foot.

It is clear, then, that the unquestionably difficult adoption of the metric system would not only occasion serious permanent inconvenience to much the greater part of our population without the justification of any ideal beauty, but would even be an obstacle to perfecting with slight and easy changes our present essentially far better system.

Additional Remarks.—To the preceding brief summary of my views, as expressed before the Engineers' Club, in 1895, I wish to add the following comments:

There are certain somewhat prevalent misconceptions as to the best standard and unit of measure, the best subdivision of the unit and a compulsory change to another system.

The primary standard, or the unchanging object which can be referred to for the verification of measures in use, is, of course, not necessarily the same as the unit of those measures. The British took for a standard the pendulum beating seconds at London, of which the yard and the foot are definite parts. The French, more than 100 years ago, generously aiming at yet greater universality and freedom from any local, national or political taint; but overestimating their knowledge and skill, undertook to use no less far-fetched and difficult a natural primary standard than a meridian of the earth; unaware that no two meridians

were of equal length, and arriving at a somewhat erroneous measurement of the French meridian selected. It has, however, been conceded, that, rather than refer again with such enormous pains to the natural primary standard, it is better to continue to use a secondary standard, the metallic meter so erroneously prepared. The meter, therefore, has been stripped of the only ideal beauty it was ever supposed to have. Moreover, it does not have even the practical advantage of producing measures in approximate agreement with commonly used arcs of the earth's surface; for repeated strenuous efforts have never been able to bring the decimal subdivision of the quadrant into general use. The metric standard, then, is, after all, merely a French piece of metal, subject to the vicissitudes of objects treasured in some particular country and place.

Units appear at times to be confounded with standards. At any rate, some admirers of the French system, with shallow wit and without looking beneath the merest surface of things, deride the humble origin of our ancient measures, taking them to be not mythically but really based upon the barleycorn and the human foot as standards. Those jokers must be seriously shocked to think that our early ancestors should not have used micrometers to gage the size of their fishhooks, arrowheads, bows, oars and canoes. Obviously, it was in their days not only natural, but the wisest possible plan to take the commonest things for units of length, especially some dimension of the ever handy human body, the finger, the thumb, the hand, the span, the foot, the cubit, the yard, the pace and the fathom. Of them all, the foot was, in the progress of enlightenment, and in all countries from the far East to the far West, found to be the most suitable unit of length for ordinary measures; though a decidedly longer unit, like the yard or fathom or even a longer one, was convenient for very long objects, such as cloth, or ropes, or land; and a shorter unit, like the inch, for small or nicely fitting objects, such as the parts of machinery. No inconvenience whatever arises from the co-existence of several such units; but in the comparatively rare cases of wishing to convert from one to another, it is desirable that their ratios should be somewhat simple, as in the conversion from feet to yards or fathoms.

The selection of a unit of measures should be guided by its convenience to the greatest number who use them most; not merely its convenience to the comparatively small number of chemists, electricians, geodesists or other scholars who may consider their computations to be facilitated by one or the other system, and that everybody else must be benefited in like manner, or to the comparatively few exporters of merchandise to Latin countries; but by the convenience of the unit in its almost infinitely more frequent use by the vastly more numerous whole population, by the carpenter, the smith, the miner, the farmer, the mechanic and laborer of all kinds.

The subdivision of the unit is likewise a matter of convenience: for most men and for the most frequent reckoning, which is in the head, successive division by two or three is most convenient; but for chemists, electricians, surveyors and those who have to reckon closely, with pencil on paper, a decimal subdivision is commonly found most convenient. There is, however, no reason whatever why this little convenience of a comparatively small number should be made the occasion of putting an immensely greater number to inconvenience. Topographers in leveling find the decimal subdivision of the foot convenient, but do not require others to imitate them. Land surveyors have for 250 years used a special unit and a decimal subdivision of it, without demanding that the whole community should conform to their practice.

Decimal subdivision may facilitate computation on paper, especially in adding up many digits, but reckoning in the head is much more easily effected with a subdivision by halves or thirds. That is clearly the reason why such fractions are in constant use in the stock market, even with our much vaunted decimal currency established more than a century ago. In a multitude of cases, too, it is easier to make a computation with those easy fractions than to undertake it with the more cumbersome tenths, hundredths and thousandths. Plainly, the mental computations are by far more frequent than ciphering, and would be still more so were we not somewhat tied down to the pencil by the decimal system, as the Chinaman is to his abacus.

In sum, our present system has a more convenient primary standard of reference, more suitable units, and, on the whole, a more satisfactory method of subdivision, and is, therefore, both logically and practically superior to the French system. For men who are without those advantages, the results of many ages of experience, to urge the abandonment of such superiority is like the recommendation of the tailless fox that all his race should remove their tails also.

Anything like compulsion to adopt the metric system of weights and measures would be gross injustice, forcing downright inconvenience and expense upon much the greater part of the community, and making us perhaps seem to play the part of enthusiastic theorizers carried away with a beauty that is, in this case, really only skin-deep, but that nevertheless might well be attractive to the æsthetic disposition, and especially so to the young, the half-taught and the inexperienced, not yet reduced to the strictly practical. There may be no harm in permitting, without compulsion, the use of the sufficiently precise foreign system; and if ever its use should unexpectedly prove itself in practice to be satisfactory to anything like a majority of the public, it will be time enough to consider the discontinuance of the present equally precise and yet more soundly rational system. BENJ. SMITH LYMAN.

PHILADELPHIA, June 2, 1902.

[*To be continued.*]

Section of Photography and Microscopy.

Stated Meeting, held Thursday, May 1, 1902.

A Method of Measuring Objects in the Microscope.

By Frederic E. Ives,
Member of the Institute.

In Carpenter-Dallinger on the Microscope (seventh edition, p. 226), the following is given as the "simplest" method of measuring objects in the microscope:

"Project the magnified image of the object by any of the methods described under 'camera lucida and drawing.' If we carefully trace an outline of the image, and then, without disturbing any of the arrangements, remove the object from the stage and replace it with a 'stage micrometer,' which is simply a thin slip of glass ruled to any desired scale, such as tenths, hundredths, thousandths of an inch and upwards. Trace now the projected image of this upon the same paper, and the means are at once before us of making a comparison between the object and a known scale, both being magnified to the same extent. . . . In favor of the above method . . . it will be noted [1] that no extra apparatus is required, [2] that it is extremely simple, and [3] that it is accurate."

A quite expensive accessory, the screw micrometer eyepiece, is then referred to as the most efficient piece of apparatus for this purpose, and the use of a simple form of eyepiece micrometer, which is the most usual practice, is described as being somewhat less accurate than either of the other methods.

Even the use of an eyepiece micrometer involves a separate determination of its values for every objective and for some particular tube-length for each objective, and with that particular eyepiece which contains the scale. Any one who employs a considerable variety of objectives will require a rather formidable reference table, must work with the tube-length indicated in the table, and must use a particular eyepiece, in order to get a measurement.

It goes without saying, that a method which would give a direct reading, which would not be affected by change of objective, eyepiece or tube-length, would be more convenient and generally more desirable than the methods above described.

Such a method which I have realized consists in projecting the image of an illuminated scale in the plane of the object by means of the substage condenser. An efficient apparatus can be made for a few cents, and after it has once been adjusted by the aid of a stage micrometer, it can be brought into service at a moment's notice whenever wanted.

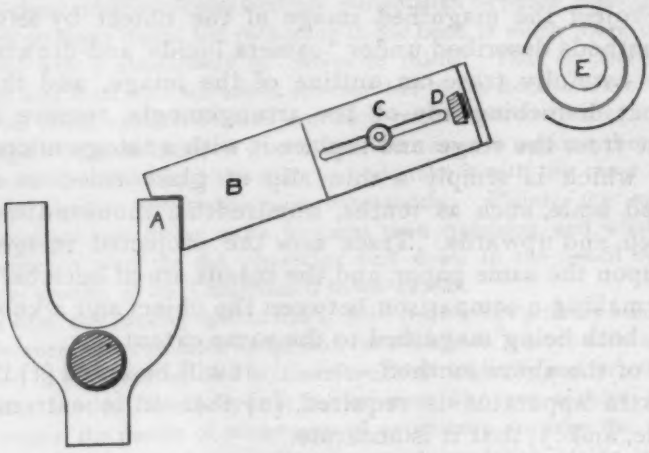


FIG. 1.

This apparatus is best made with a fixed adjustment for a particular microscope stand, and for illumination from a particular direction. I shall therefore describe the device which I am using with a Bausch & Lomb "BB" stand and a Welsbach light. Other forms of stand and other sources of illumination can readily be provided for.

In the diagram, *Fig. 1*, *A* is the base of the microscope, *B* a block of wood seven inches long (notched to fit against the microscope base and project in a particular direction, as shown), *C* is a rider with set-screw and a post and spring-clamp *D*, to hold a jeweler's saw having sixty-four teeth to the inch. *E* is the Welsbach light, diffused by a ground-

glass chimney and shielded from the eyes by a hood open only on the side towards the microscope. The source of light being on a level with the microscope, the jeweler's saw is supported in a vertical plane, directly between the light and the microscope mirror, and in this position its image can be focussed in the field of the microscope by racking back the condenser just a trifle. The image of the saw-teeth constitutes the measuring scale, which can be given any desired value, within limits, by adjusting its distance from the microscope mirror and comparing the focussed image

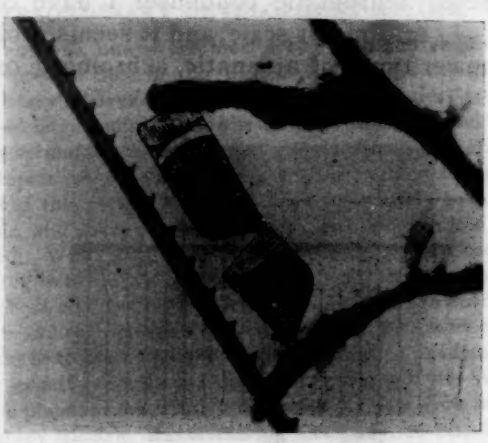


FIG. 2.

with the scale on a stage micrometer. My adjustment makes each tooth equal to one-fiftieth of a millimeter on the stage micrometer.

Of course, an engraved scale, on glass or celluloid, can be substituted for the jeweler's saw, and the apparatus may be otherwise elaborated, as by making the scale revolvable and otherwise adjustable as to position and angle, but these are refinements which I do not at present require.

When the scale is not wanted the block is pushed aside and can be brought back into position in an instant.

It is evident that in order to insure strict accuracy the scale itself must be accurately divided and must occupy a

position at right angles to a line drawn from the center of the source of light to the center of the mirror; the distance must be constant, the surfaces of the mirror must be plane, and the condenser must be capable of projecting a sufficiently sharp and undistorted image. For such measurements as would be required with low and medium-power objectives, I have found an ordinary Abbe condenser efficient by closing up its iris to sharpen the image. An achromatic Abbe condenser used in the same way will define well enough to provide a readable $\frac{1}{100}$-millimeter scale. With a better corrected achromatic condenser I have obtained a satisfactory $\frac{1}{200}$ millimeter scale, and it seems probable that one of the newer types of aplanatic, achromatic or apochro-

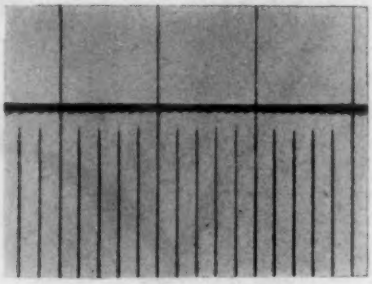


FIG. 3.

matic condensers, now regarded by some authorities as almost indispensable for really critical work with the microscope, would define a scale to measure with sufficient accuracy to $\frac{1}{1000}$ millimeter. The expensive and comparatively troublesome Filar micrometer will make still smaller and more accurate measurements, which, however, are very seldom required and are not provided for in the equipment of the great majority of microscopists.

Fig. 2 is a photograph of an image of both object and scale as seen in the field of the microscope, but with a coarser scale than I have described.

Fig. 3 is a photograph of a $\frac{1}{50}$-millimeter projected scale in the field with a $\frac{1}{100}$-millimeter stage micrometer.

Erratum.

Correct date of meeting of Electrical Section, at which Mr. C. J. Reed's paper on "Electro-chemical Polarization" was presented, to read November 21, 1901.

W. H. W.

Notes and Comments.

EXTRAORDINARY DEVELOPMENT AT THE "SOO."

Without question, one of the most active scenes of engineering development at the present time in the United States is the "Soo" district, at the point on St. Mary's River where Lake Superior empties into Lake Huron, and where two large industrial towns on the American and Canadian sides have already sprung up. At this point the river has a fall of about nineteen feet at the Rapids in a distance of 3,000 feet, developing at least 175,000 horse-power. Part of this energy, hitherto wasted, has already been utilized on the Canadian side, and at the present moment two other kindred enterprises are being pushed. While the development will be in sharp contrast to that at Niagara, owing to the slight head of water at the "Soo" as compared with an average of about 200 feet at the great cataract, the two enterprises compare in magnitude and each presents unique features. Data were recently given in these columns as to the new work at Niagara on the Canadian side, for which three of the largest generators in the world are being built. A contrast is presented by the plans for the "Soo," where for the new work now to be carried out, the Stanley Electric Manufacturing Company, of Pittsfield, Mass., has been awarded a contract for no fewer than 40 generators, etc., the impulse wheels to drive which are already in place. The building in which these machines will be installed is itself over a quarter of a mile long and three stories in height, and the power canal which will divert water from the Rapids to the wheels has also been dug and finished, 210 feet wide, 20 feet deep and 5 miles long. This development is on the American side of Sault Ste. Marie.

The amount of power to be developed will, it is stated, approximate 100,000 horse-power, and this extraordinary plant will unquestionably be by far the largest hydro electric equipment under one roof in the world. The current will be utilized by the Clergue syndicate, which is backed mainly by Philadelphia capital, for the rolling mills, pulp mills, electro-chemical works and other industries of the Consolidated Lake Superior Company and concerns of a similar character, while it is believed that a large part of the current will also be transmitted to Canada. The electrical contract is now being carried out and the apparatus will be installed forthwith. It is curious to think that the same water thus used so much higher up on the chain of lakes should again yield its energy at Niagara. The current generated will be three-phase, 30 cycles.—*Electrical World.*

THE CENSUS FIGURES FOR THE METALLURGICAL INDUSTRIES.

Although there have been some innovations in the iron and steel industry since the gathering of statistics for the census of 1900, and the returns therefore have lost some of the significance which they might have otherwise, the figures still are possessed of both intrinsic and relative value.

It is notable that the iron and steel industry is given second place in the list of selected industries prepared by the Bureau of Manufactures, textile industries taking first place, with the total value of the products placed at $966,924,835. If the metal industries are grouped together, however, as are the textile manufactures, the metal products take precedence, the value of the iron and steel, lead, copper and zinc manufactures aggregating $1,194,545,506. And the metal industries, too, seem to be the more profitable, as the aggregate capital invested, as given by Mr. North, the Chief Statistician, is $719,395,848, against $1,066,032,937 invested in the manufacture of textiles.

This is a matter of no great concern, however, and among separate industries iron and steel is far in the lead, giving evidence of the greatest vitality. Not only is the value of the product greater than that of any other industry, but a larger amount of money is distributed to the wage-earner and, with the exception of the woolen, cotton and lumber interests, employment is given to a larger number of workers; indeed, in the engagement of skilled labor the iron and steel industry stands pre-eminent. The total number of men employed was 226,161, who received $122,710,193 in wages, the rolling mills and steel works leading with 183,023 men, who earned $102,238,692, while the blast furnaces employed 39,241 men, who were paid $18,484,400.

In 1900 there were 725 establishments—including 57 making tin and terne plates—engaged in the iron and steel industry, an increase of six plants, or a gain of 0·8 per cent., since 1890. It is a matter of interest that there were 438 active rolling mills and steel plants in 1900—a gain of 43 since 1890—while there were only 223 blast furnaces blowing, against 304 active stacks in 1890. The number of forges and bloomeries was reduced from 20 in 1890 to 7 in 1900.

The capital invested in the 725 active establishments in 1900 was $580,041,710, employment being given to 226,161 workers, earning $122,710,193, while the salaries paid to the 9,544 officers and clerks engaged amounted to $12,028,811. The cost of the materials used for conversion was $549,127,082; miscellaneous expenses were $32,570,556, and the value of the manufactured products, as previously stated, was $835,759,034. The latter is made up of $596,588,034, the value of the manufactures from the rolling mills and steel works; $206,756,557, the value of the output of the furnaces; $31,892,011, the value of the tin and terne plate, and $522,432, the value of the products from the forges and bloomeries.

In 1900 there were 117 plants engaged in the smelting and refining of metals, 39 in the smelting and refining of lead, 47 in copper and 31 in zinc. The total capital invested in the smelters and refineries was $139,354,138, employing 1,121 officials and clerks, drawing salaries amounting to $2,150,018, distributing $15,937,626 to 24,504 wage-earners, expending $279,655,350 for raw materials and turning out manufactured products valued at $358,786,472.

—*Iron Age.*

Franklin Institute.

[*Proceedings of the Stated Meeting held Wednesday, June 18, 1902.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 18, 1902.

Vice-President WASHINGTON JONES in the chair.

Present, 60 members and visitors.

Additions to membership since last report, 5.

Dr. J. Merritt Matthews, of Philadelphia, presented an informal communication on "Viscose and Its Applications," illustrating the subject by the exhibition of numerous specimens. The speaker was accorded the thanks of the meeting.

Mr. J. Allen Heany described and exhibited in operation an improved Enclosed Arc Lamp of his invention.

Mr. E. D. Dorsey gave a brief account of the development of devices intended for addressing envelopes, wrappers, etc., for mailing and other purposes; and described and showed in operation an improved apparatus of this class, called the "Addressograph," for which special advantages were claimed.

The several subjects presented at the meeting were severally referred to the Committee on Science and the Arts for investigation and report.

Mr. W. N. Jennings showed a number of lantern slides from photographs taken by him from the top of the Washington Monument.

Mr. John Carbutt followed with a series of slides from photographs of star clusters and nebulæ, made by Professor Ritchie, of Yerkes Observatory.

Action on certain pending amendments to the By-Laws of the Institute was deferred. Adjourned.

WM. H. WAHL, *Secretary.*

Committee on Science and the Arts.

(*Abstract of proceedings of the stated meeting held Wednesday, June 4, 1902.*)

MR. THOMAS P. CONARD in the chair.

The following reports were adopted:

(No. 2210.) *A Theory of Electricity.*—John Trewhella, Coatesville, Pa.

(An advisory report.)

(No. 2212.) *Rheostat.*—Charles Wirt, Philadelphia.

ABSTRACT.—This apparatus is the subject of letters-patent of the United States, No. 633,172, September 19, 1899, granted to applicant.

The special novelty of the apparatus resides in the use of a continuous strip of resistance material without joints. This strip is a ribbon of metallic alloy coated on one side with an insulating material (such as flake mica), held in place by shellac, so that when the strip is wound in a flat coil there is a layer of insulation between each layer of conducting material. In making these strips into a rheostat they are wound upon a mandrel of flat oval section, a certain number of turns being wound one on top of the other, when a

slight sideways shifting allows another series of turns to be wound upon the mandrel without breaking the continuity of the strip itself.

When a sufficient number of these flat coils have been wound upon the mandrel they are slid off, and the coils are arranged in a circle upon a plate which forms the back of the instrument. The necessary contact strips are then placed in position, one on the face of each coil, and extending the full length and width of same. The front plate, with the necessary insulation, etc., is placed upon these, and the whole subjected to heavy compression, while a steel ring is spun over the outer edges of the plates, making the compression permanent and leaving the instrument ready for the placing of the center spindle and contact arm.

The advantages claimed for these rheostats are: small size combined with large capacity; a large subdivision of the resistance without undue expense; small liability to damage owing to the absence of all soldered joints; and long life for the same reason.

The investigating body subjected one of these rheostats, suitable for a 5-horsepower motor, to the severe test of a large number of heatings and coolings, which were estimated to be the equivalent of two years' service.

On dismantling the instrument it was found, at the conclusion of the tests, that none of the contact strips had been moved or shifted, nor had the resistance strip apparently sustained any damage. The insulation between the layers of the coils seemed in perfect condition, and the metallic contacts between the strip and contact plates showed no deterioration except where the cooling water (used in the tests) had penetrated.

The report concludes that the claims made for the Wirt rheostat are sustained. The Scott award is recommended to the inventor. [*Sub-Committee.*—T. Carpenter Smith, Chairman; Clayton W. Pike.]

(No. 2228.) *Photomicrographic Device.*—Frederic E. Ives, Philadelphia.

ABSTRACT.—The object of this device is to improve upon existing appliances for photographing the visible field of a microscope or other optical instrument, and especially to serve the convenience of the operator by permitting the instrument, when in use, to remain undisturbed while its field is being photographed, and also to determine with greater facility the ratio of magnitude between the visible field and its photographed reproduction.

[For a detailed description of the apparatus, with illustrations, the reader is referred to this JOURNAL, Vol. CLIII, 371, May, 1902, ART., "A Photomicrographic Device," Ives.]

The investigators say in their report that the novelty of this apparatus consists in the simplicity of the means by which the camera and the microscope may be brought into combination or disengaged, and the gist of the invention lies in the ingenuity with which the simplicity of the apparatus is maintained, together with a thorough adaptability for its purpose.

"In recognition of the value of this microscopic camera in materially facilitating the production of photographs with the microscope," the award of the Edward Longstreth Medal of Merit is made to the inventor. [*Sub-Committee.*—Louis E. Levy, Chairman; H. R. Heyl, Samuel Sartain.]

The following reports passed first reading:

(No. 2174.) *Cipher-Code System.*—Willis J. Roussell, New Orleans, La.

(No. 2221.) *Electric Elevator for Private Residences.*—Otis Elevator Company, New York.

WM. H. WAHL, *Secretary.*